JOURNAL OF THE AERONAUTICAL SCIENCES

VOLUME 3 NUMBER 8

JUNE, 1936

Published by the

INSTITUTE OF THE AERONAUTICAL SCIENCES, INC.

INSTITUTE OF THE AERONAUTICAL SCIENCES, INC.

President
GLENN L. MARTIN

Past Presidents
J. C. HUNSAKER
CHARLES L. LAWRANCE
D. W. DOUGLAS

Vice Presidents
EDWIN E. ALDRIN
C. L. EGTVEDT
G. W. LEWIS
CLARK B. MILLIKAN
EUGENE E. WILSON

Treasurer
SHERMAN M. FAIRCHILD

Secretary
LESTER D. GARDNER

Assistant Secretary
GEORGE R. FORMAN

Comptroller
C. E. SINCLAIR

COUNCIL

EDWIN E. ALDRIN
CHARLES H. CHATFIELD
CHARLES H. COLVIN
LUIS DE FLOREZ
SHERMAN M. FAIRCHILD
JAMES H. KIMBALL
PAUL KOLLSMAN
CHARLES L. LAWRANCE
ARTHUR NUTT
EARL D. OSBORN
ELMER A. SPERRY, JR.
T. P. WRIGHT

ADVISORY BOARD

EDMUND T. ALLEN
VINCENT BENDIX
LYMAN J. BRIGGS
V. E. CLARK
J. H. DOOLITTLE
JACK FRYE
W. R. GREGG
LEROY R. GRUMMAN
HALL L. HIBBARD
J. H. KINDELBERGER
E. J. KING
ALEXANDER KLEMIN
I. MACHLIN LADDON
GROVER LOENING
JOHN K. NORTHROP
A. A. PRIESTER
A. E. RAYMOND
H. J. E. REID
JAMES M. SHOEMAKER
E. A. STALKER
GERARD F. VULTEE
O. WESTOVER

JOURNAL OF THE AERONAUTICAL SCIENCES

VOL. 3 JUNE, 1936 NO. 8

Editor: J. C. HUNSAKER, *Massachusetts Institute of Technology*

PUBLISHED MONTHLY BY THE INSTITUTE OF THE AERONAUTICAL SCIENCES, INC.
AT 99–129 NORTH BROADWAY, ALBANY, NEW YORK

The JOURNAL OF THE AERONAUTICAL SCIENCES is the official publication of the Institute of the Aeronautical Sciences, Inc., and is devoted to papers on experimental, theoretical, and applied science as employed in aeronautics.

Manuscripts for publication, proofs, and all correspondence should be addressed to the Editorial Secretary of the JOURNAL. Subscription price: $5.00 per year; single copies, 50c. Foreign subscription price: $6.00 per year; single copies, 60c.

Correspondence regarding subscriptions may be addressed to Publication Office, 99–129 North Broadway, Albany, N. Y., or to the Editorial Office of the JOURNAL OF THE AERONAUTICAL SCIENCES, 5431 R. C. A. Building, Rockefeller Center, New York, New York. Cable Address: INSAEROSCI.

Entered as Second Class Matter at Post Office, Albany, N. Y., October 2, 1935. Acceptance for mailing at a special rate of postage provided for in the Act of October 3, 1917, embodied in paragraph 4, section 412, P. L. & R. authorized February 17, 1934.

JOURNAL OF THE AERONAUTICAL SCIENCES

CONTENTS

Technological Developments of the Curtiss-Wright "Coupe" . ALBERT E. LOMBARD, JR. 267

A Note on Fuselages of Low Drag . . . JOHN R. MARKHAM AND SHATSWELL OBER 276

Propeller Design As Applied to Windmills . . . . . E. N. FALES 278

Distribution of Heat Loss to the Jackets in an Internal Combustion Engine Cylinder . . . . . C. FAYETTE TAYLOR 282

The Design of a Stratosphere Rocket . . . . . ALFRED AFRICANO 287

An Air Spoiler . . . . . A. A. MERRILL 291

Eleventh Annual Aircraft Engineering Research Conference of the National Advisory Committee for Aeronautics 292

Institute Notes 296

Aeronautical Reviews 299

Book Reviews

Engine Bearing Loading, (*William Samuels*) . . . . . J. R. Custer 297

Annuaire de L'APNA . . . . . Lester D. Gardner 297

Aerodynamic Theory, Vol. VI. (*W. F. Durand, Editor-in-Chief*) . . . . . J. C. Hunsaker 298

VOLUME 3 JUNE, 1936 NUMBER 8

An Appreciation

to

Corporate Members

of the

Institute of the Aeronautical Sciences

The publication of the Journal of the Aeronautical Sciences is made possible by Corporate Members who are manufacturers or operators of aircraft or producers of equipment or supplies used in aeronautics who contribute annually to the Institute.

The dues of Corporate Members range from a minimum of $200 to a maximum of $2500.

The income from these dues enabled the Institute to discontinue advertisements in the Journal and use the pages for editorial material. The Members of the Institute appreciate the cooperation of Corporate Members in providing funds for assisting the work of the Institute and for the publication of the Journal.

The B. G. Corporation

Curtiss-Wright Corporation

- Curtiss Aeroplane & Motor Company
- Curtiss-Wright Airplane Company
- Wright Aeronautical Corporation

Douglas Aircraft Company

Eclipse Aviation Corporation

Edo Aircraft Corporation

Ethyl Gasoline Corporation

Fairchild Aviation Corporation

- Fairchild Aircraft Corporation
- Fairchild Aerial Camera Corporation
- Fairchild Aerial Surveys, Inc.
- Ranger Engineering Corporation

Glenn L. Martin Company

The Goodyear Tire & Rubber Company

Kollsman Instrument Company

The Northrop Corporation

Socony-Vacuum Oil Company

Sperry Gyroscope Company

Stanavo Specification Board

Summerill Tubing Company

The Texas Company

United Aircraft Manufacturing Corporation

- Chance Vought Aircraft
- Hamilton Standard Propellers
- Pratt & Whitney Aircraft
- Sikorsky Aircraft

Note. The above companies joined the Institute as Corporate Members before any special invitations were issued by the Council. Other names will be added from time to time as the Council's invitations are accepted.

JOURNAL OF THE AERONAUTICAL SCIENCES

Volume 3 JUNE, 1936 Number 8

Technological Developments of the Curtiss-Wright "Coupe"

Presented by T. P. Wright at the Pacific Coast Meeting of the I. Ae. S., February 7, 1936

ALBERT E. LOMBARD, Jr., *Curtiss-Wright Airplane Company*

SUMMARY

THIS paper presents the results of research which was carried out in the development of the Curtiss-Wright "Coupe," a two place, all-metal cantilever monoplane. Wind tunnel data of the effects of split flaps is reported, as is also that dealing with the drag of certain features of the airplane. Structural tests of a series of stiffened sheet metal panels in edge compression are reported which show good correlation with the "effective width" conception of the action of thin sheet in the buckled state. Comparison is made of fifteen types of stiffeners suitable for use on reinforced sheet structures subjected to compression. The results of flight tests and theoretical studies combined with wind tunnel tests of airfoils are discussed, which indicate that the stalling characteristics of tapered monoplane wings can be appreciably improved without the use of aerodynamic twist, by using a highly cambered airfoil at the tip having a high value of $C_{L\ max.}$.

AERODYNAMIC DESIGN

Wind tunnel tests were conducted on a 1/12 scale model of the preliminary design in the Buffalo wind tunnel of Curtiss Aeroplane and Motor Company, shown in Fig. 1. These tests included the effect on the lift and pitching moments of the installation of split flaps, 20% of the wing chord, 42% of the span, set at 60 degrees, (Fig. 2). It is seen that the flaps produced a positive pitching moment (tail heavy) on the complete model, which is desirable since thereby the airplane can be glided at a reduced airspeed after the flaps have been extended without retrimming the elevator. This effect has been checked in flight test and found to simplify controlling the glide to the field. With flaps down, the speed of trim is about 10 m.p.h. less than with the flaps neutral, so that a constant margin is maintained over the stalling speed which is also reduced 10 m.p.h. by the flaps. Fig. 2 further shows that the middle portion of the flap is more effective in producing this positive moment than in increasing the maximum lift coefficient.

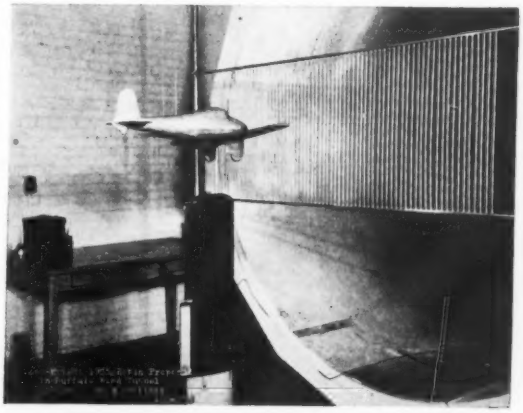


FIG. 1. Model in Buffalo wind tunnel of Curtiss Aeroplane and Motor Company.

The results of certain of the drag tests run at 80 m.p.h. are shown in Figs. 3 and 4. Interpreted in the terms of the two units, "percentage of total airplane drag," and "miles per hour," these items become:

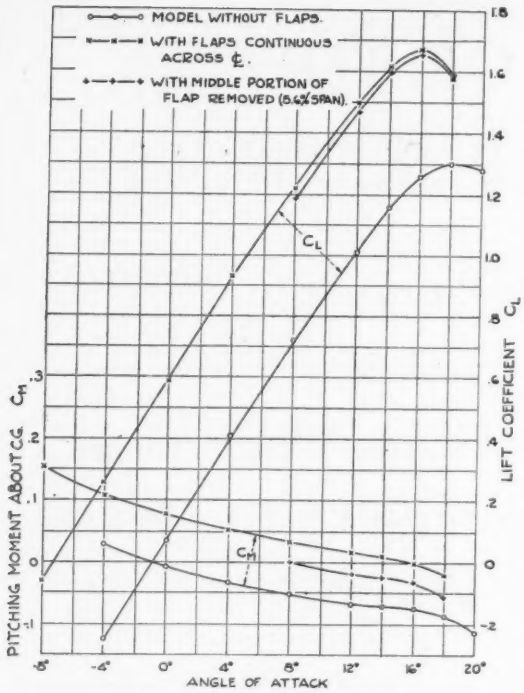

MODEL WITHOUT FLAPS.
WITH FLAPS CONTINUOUS ACROSS ℄.
WITH MIDDLE PORTION OF FLAP REMOVED (54% SPAN).
C_L
C_M
PITCHING MOMENT ABOUT C.G. C_M
LIFT COEFFICIENT C_L
ANGLE OF ATTACK
-8° -4° 0° 4° 8° 12° 16° 20°
-.1 0 .1 .2 .3
-2 0 .2 .4 .6 .8 1.0 1.2 1.4 1.6 1.8

FIG. 2 EFFECTS OF FLAPS.

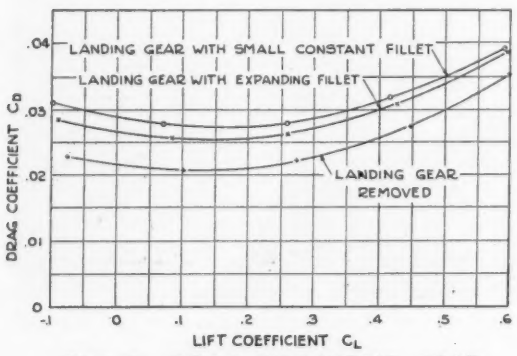

LANDING GEAR WITH SMALL CONSTANT FILLET
LANDING GEAR WITH EXPANDING FILLET
LANDING GEAR REMOVED
DRAG COEFFICIENT C_D
LIFT COEFFICIENT C_L
0 .01 .02 .03 .04
-.1 0 .1 .2 .3 .4 .5 .6

FIG. 3. DRAG OF LANDING GEAR.

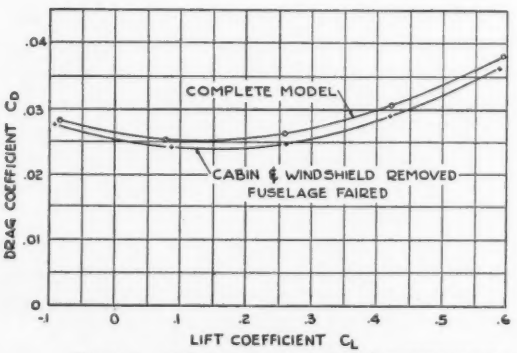

COMPLETE MODEL
CABIN & WINDSHIELD REMOVED-FUSELAGE FAIRED
DRAG COEFFICIENT C_D
LIFT COEFFICIENT C_L
0 .01 .02 .03 .04
-.1 0 .1 .2 .3 .4 .5 .6

FIG. 4. DRAG OF CABIN & WINDSHIELD.

TABLE I TESTS OF STIFFENED 24ST ALCLAD PANELS

	STIFFENER TYPE	MATERIAL	STIFFENER AREA SQ. IN.	PANEL THICKNESS IN.	NO. OF STIFFENERS	LOAD CARRIED LBS.	TOTAL EFFECTIVE AREA SQ. IN.	EFFECTIVE STRESS LB./SQ. IN.	AVERAGE EFFECTIVE STRESS LB./SQ. IN.
1	43 .027	24ST ALCLAD	.0617	.0315	2	5560	.269	20,600	
			.0606	.0317	2	5270	.272	19,400	20,000
2	49 .025	24ST ALCLAD	.0753	.0321	2	7490	.289	25,900	
			.0739	.0315	2	7870	.280	28,100	27,000
3	124 .020	24ST ALCLAD	.0794	.0320	2	7490	.297	25,200	
			.0817	.0318	2	7180	.301	23,700	24,500
4	65 .032	24ST ALCLAD	.0777	.0319	2	9890	.344	28,700	
			.0771	.0315	2	7300	.289	25,200	27,000
5	88 .032	24ST ALCLAD	.0944	.0317	2	8060	.329	24,500	
			.1034	.0320	2	8210	.351	23,400	24,000
6	100 .052	24ST ALCLAD	.0773	.0318	2	9790	.276	35,500	
			.0774	.0320	2	9550	.279	34,200	34,900
7	125 .032	24ST ALCLAD	.0764	.0317	2	8640	.280	30,800	
			.0757	.0317	2	8740	.277	31,600	
			.0745	.0318	1	5650	.179	31,600	31,800
			.0732	.0328	1	6040	.183	33,000	
8	84 .025	24ST ALCLAD	.0764	.0326	2	8060	.291	27,700	
			.0763	.0318	2	8550	.285	29,500	28,600
9	.75 .032	17ST TUBE	.1009	.0318	2	9430	.326	29,000	
			.0961	.0315	2	9310	.323	28,800	28,900
10	75 .037 SMALL SPACE	17ST TUBE	.0785*	.0315	2	8650	.287*	30,800*	
			.0785*	.0322	2	8490	.291*	29,900*	30,400*
11	69 .047	24ST EXTRUDED	.0882	.0323	1	6470	.193	34,600	
			.0866	.0324	1	6510	.195	33,700	
			.0860	.0318	2	9400	.306	30,700	
			.0850	.0315	2	10170	.302	33,700	
			.0886	.0318	2	9790	.309	32,100	
			.0882	.0322	2	10210	.304	33,600	
			.0870	.0312	2	9740	.292	33,400	
			.0870	.0306	2	9350	.289	32,400	
			.0878	.0322	3	11590	.420	27,600	
			.0886	.0320	3	12060	.422	28,600	
			.0870	.0310	4	16090	.501	32,100	
			.0870	.0306	4	16280	.498	32,700	
			.0850	.0265	1	5860	.167	35,300	
			.0868	.0272	1	5850	.169	34,600	
			.0862	.0274	2	8730	.271	31,100	
			.0850	.0275	2	9460	.276	33,100	
			.0835	.0208	1	4665	.144	32,400	
			.0835	.0207	1	4640	.143	32,400	
12	88 .063	24ST EXTRUDED	.104	.0313	2	11020	.328	33,600	
			.104	.0312	2	11300	.326	34,700	34,200
13	109 .080	24ST EXTRUDED	.168	.0303	2	16280	.448	36,400	
			.168	.0306	2	16560	.446	37,200	36,800
14	89 .047 ½ HOLE SPACE	24ST EXTRUDED	.0756*	.0316	2	8360	.281*	29,500*	
			.0757*	.0324	2	8750	.284*	30,900*	30,200*
15	.69 .050	24ST EXTRUDED	.172	.0305	2	15810	.487	32,500	
			.172	.0306	2	15580	.483	31,900	32,200

* AVERAGE AREA USED (=VOLUME/LENGTH).

	Percentage of Total Drag	Speed Effect
Landing gear drag:		
With constant fillet.....	18%	7 m.p.h.
With expanding fillet.....	13%	5 m.p.h.
Reduction due to expanding fillet	5%	2 m.p.h.
Cabin and windshield drag: (compared to smoothly faired fuselage, cabin removed)..	5%	2 m.p.h.

Structural Design

Edge compression tests of sheet metal panels of 24ST Alclad stiffened by various types of formed and extruded shapes were carried out to check the "effective width" method for computing the strength of stiffened sheet metal panels, and to select a suitable stiffener type.

The panel tests indicate that the "effective width" method, developed by von Karman, Sechler and Donnell,[1,2] and by Lundquist[3] (Method C), which assumes the stiffener and an effective width of adjacent sheet to act as a unit, all at the same stress, gives good coordination of the results. Referring to Table 1, it is seen that the "effective stresses" for stiffeners Type 7 and Type 11, which were tested on panels of various gauges with various numbers of stiffeners, lie within narrow bands which are no broader than the individual variations on supposedly identical panels. One exception to this close correlation occurred in the two tests of stiffener Type 11 with .032 sheet and three stiffeners per panel in which the sheet failed prematurely due, apparently, to a peculiarity of the rivet pattern on those panels, but this exception is not believed to invalidate the rule established. The "effective width" method of analysis is considered very satisfactory.

Stiffener Selection

In selecting a suitable stiffener type, certain restrictions were necessarily placed on the type of stiffener and its method of attachment to the sheet. These restrictions were:

(1) The stiffener should be of a type that attaches to the wing skin with one row of 1/8 inch dural modified brazier head rivets spaced 1 inch apart.

(2) The stiffener should be of a type suitable for use where the rib spacing would be approximately 20 inches.

(3) The stiffener should have sufficient area and strength such that, when used with .032 inch thick 24ST Alclad, the stiffener spacing at the root of the wings need be not less than 4 inches. This third requirement was only partially adhered to.

The tests are summarized in Table 1. It was endeavored to test representative sections of all types, some obviously designed for ease of fabrication, some for high structural efficiency. Inasmuch as any stiffener could be made somewhat larger or somewhat smaller if the area was not consistent with the load to be carried, the final selection of the stiffener type was based on the maximum effective stress which the stiffener was able to carry.

The eligible types for general use were Types 1 to 12. Types 13 to 15 were intended for use in special places and on other models involving higher loads. Of the "eligible" types, the formed-up stiffener, Type 6, was the strongest. This stiffener had several desirable characteristics in its shape and design which are worthy of comment:

(1) This stiffener had sufficient depth for the length tested to prevent failure by bowing as an Euler column.

(2) This stiffener was made of sufficiently thick material that it did not buckle locally. This characteristic was made possible by the fact that the stiffener had a small developed width. It can be generally concluded that the developed width of stiffeners should be as small as is consistent with the desired depth for Euler strength.

(3) The formed bulb of this stiffener was so shaped that the stiffener was well supported laterally without unduly stressing the free edge to cause it to roll out flat.

(4) The distance from the vertical leg of the stiffener to the line of rivets was small, thus enabling the vertical leg to give considerable support to the sheet panel.

(5) The upturned roll on the free edge of the riveted leg offered support to this leg and to the attached sheet.

The extruded stiffeners, Types 11 and 12, which were next best in order of merit, were selected for actual use because of:

(1) The high maximum stress which they developed,

(2) The manner in which they failed without sudden collapse so that after failure they were still able to carry a large percentage of their maximum load,

(3) The uniformity of manufacture of the extruded shapes, and

(4) The low fabricated cost of the extruded shapes.

It should be noted in passing that the extruded shapes were made of 24ST aluminum alloy, while the formed-up stiffeners, Type 6 specifically, were made of 24ST Alclad which is approximately 10% weaker than straight 24ST. Presumably, if the formed-up stiffener, Type 6, were made of pure 24ST it would be considerably stronger than the extruded shapes, but corrosion difficulties prevent the use of unprotected 24ST in thin sheets.

Test Equipment

All the sheet metal panels were supported in the framework, Fig. 5. The load was applied to each specimen by blocks which clamped on the ends of the sheet. The stiffeners, which butted against the steel face plates, were finished on the ends and accurately attached to the sheets to provide the correct

---

[1] Th. von Karman, E. E. Sechler, and Donnell, *The Strength of Thin Plates in Compression*, Applied Mechanics Transactions of A.S.M.E., June, 1932.

[2] E. E. Sechler, *The Ultimate Compressive Strength of Thin Sheet Metal Panels*, Thesis at Calif. Inst. of Tech. 1934.

[3] Eugene E. Lundquist, *Comparison of Three Methods for Calculating the Compressive Strength of Flat and Slightly Curved Sheet and Stiffener Combinations*, NACA Tech. Note No. 455, 1933.

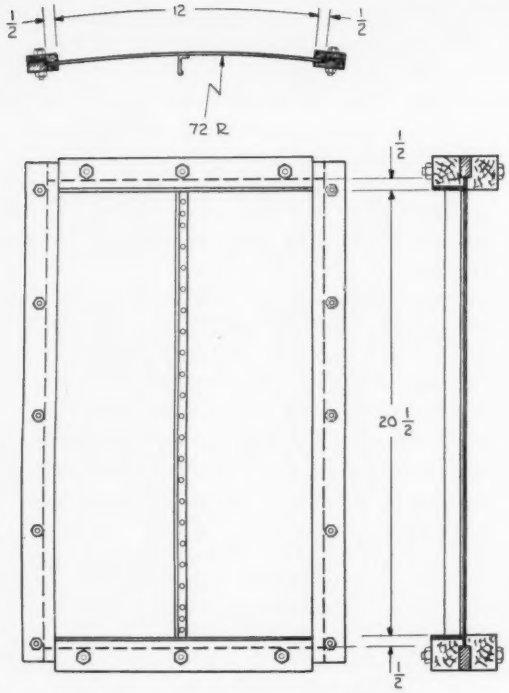


FIG. 5. TEST JIG FRAME

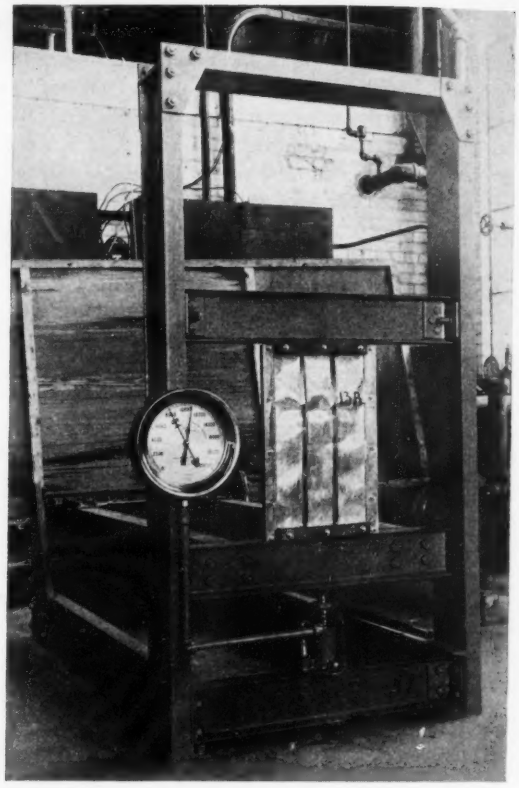


FIG. 6. Hydraulic test machine for sheet metal panels.

overhang of the sheet on the end to fit the depth of the clamping blocks. In order to take care of small variations in the ends of the stiffeners, small brass shims (.002 in. to .010 in. thick) were inserted until they were tight before the load was applied.

The vertical guides of this frame were made of steel and held to the 12 inch spacing by steel bars across the back. The thickness of the slot thru which the sheet could slide was accurately maintained by clamping shims between the bars slightly thicker than the sheet to be tested.

This method of supporting the edges of the sheet was found to be very satisfactory when testing panels with stiffeners. On such panels the buckling was always more severe in the middle of the panels, and the failures always occurred in the middle of the panels —never along the edges—at the instant when the stiffeners failed. The frictional load carried in the guides, up to the point of failure of the stiffeners, could be only a relatively small percentage of the total load in the sheet edges. Previous to the time of failure the guides would drop freely of their own weight whenever the load was removed. It is estimated that the frictional load in the guides increased the observed maximum load by possibly 50 pounds, which is considered negligible.

The testing machine shown in the photograph, Fig. 6, developed after the fashion of the one described, (see Reference 2), incorporates a hydraulic jack with a maximum load capacity of 20,000 pounds.

Method Used to Compute Stress in Stiffener and Sheet in Panel Tests

Reference 2 shows that the load carried by a simply supported, unstiffened sheet metal panel can be represented by the formula

$$P = C t^2 \sqrt{E \sigma},$$

and the "effective width" can be written

$$2w = C t \sqrt{E / \sigma},$$

in which

C is a function of η and λ as shown in Fig. 9.

$$\eta = (b / R) \sqrt{E / \sigma}$$

$$\lambda = (t / b) \sqrt{E / \sigma}$$

E is Young's modulus of elasticity.

σ is stress at the supported edge of a panel and also, in the case of stiffened panels, the stress in the stiffener and adjacent sheet (of effective width = 2 w).

t is thickness of the sheet.

b is width of sheet panels between supports.

R is radius of curvature of sheet.

The curves of C given in Fig. 9 for the range of η and λ encountered in the wings were derived from data

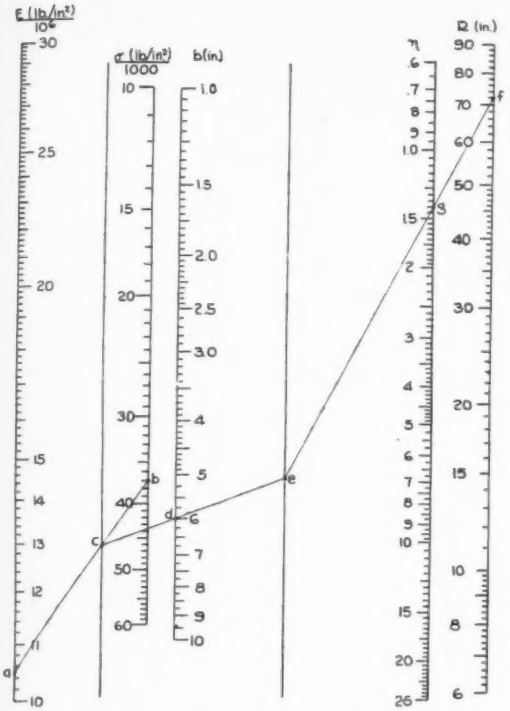


FIG. 7 SOLUTION OF $\eta = \frac{b}{R}\sqrt{\frac{E}{\sigma}}$

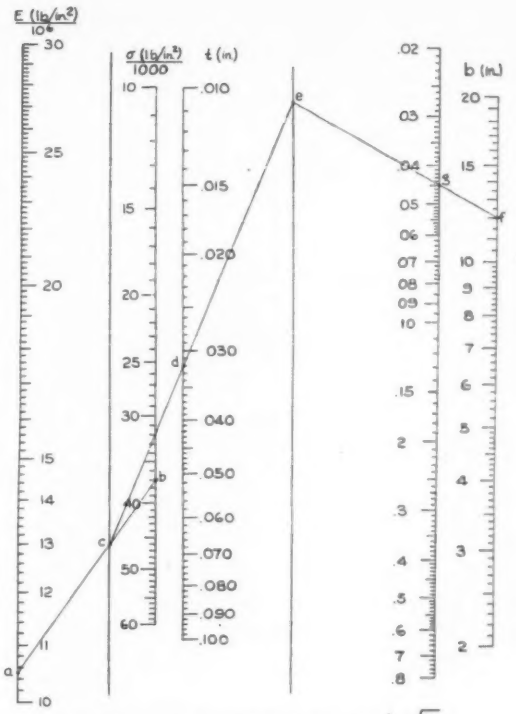


FIG. 8. SOLUTION OF $\lambda = \frac{t}{b}\sqrt{\frac{E}{\sigma}}$

of Reference 2. The nomograms, Figs. 7, 8, 10 and 11, were developed to simplify the computation of the parameters and the values of $\hat{2}$ w and P.

The assumed stress distribution in the stiffeners and sheet of the panel tests is shown in Fig. 12, in which the stresses in the stiffeners and adjacent sheet elements and in the edges of the sheet are all the same inasmuch as the shortening of the panel under load is the same at all points. Because of the support offered the sheet by the side guides, it was assumed also that all the width of the sheet inside the guides would act effectively at the maximum stress. The justification of this assumed stress distribution is believed to lie in the close correlation of the tests of the stiffeners Types 7 and 11, Table 1.

Wing Static Test

A complete wing for one side was static tested to the full design loads for high angle of attack and inverted flight. This wing, designed to close margins in accordance with the method as developed in the panel tests, carried the design loads without failure. Clips and fittings, designed according to this assumed distribution of stress in the sheet and stiffener, were all found satisfactory. These facts speak for the practical applicability of the method of analysis to the design of all-metal aircraft.

Flight Tests

The most interesting part of the flight test program was that devoted to the stalling characteristics in which modifications were effected in the wing contour which enabled the airplane to be stalled in a smooth and controllable manner.

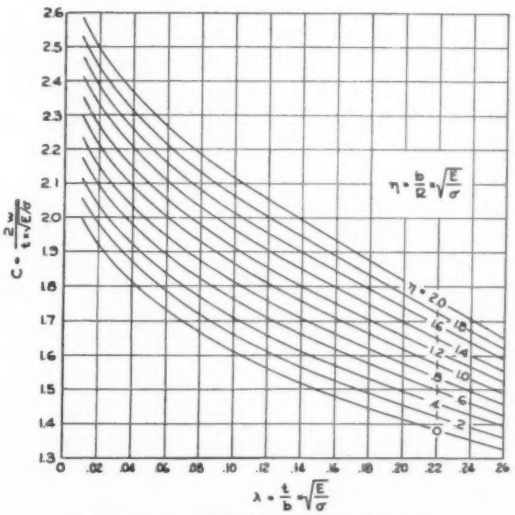


FIG. 9 EVALUATION OF C.

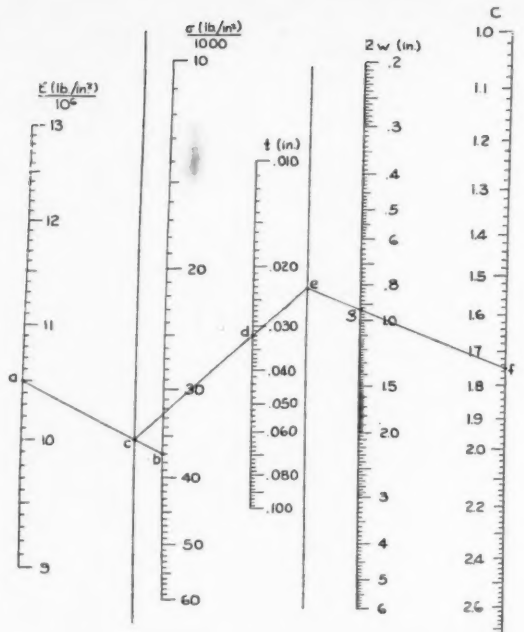


FIG. 10. SOLUTION OF $2w = Ct\sqrt{E/\sigma}$

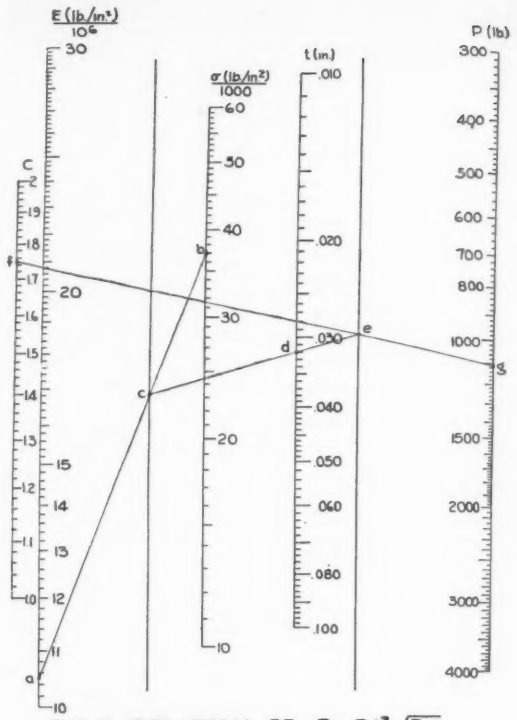


FIG. 11. SOLUTION OF $P = Ct^2\sqrt{E\sigma}$

As originally flown, the airplane had a straight tapered wing with an N.A.C.A. 2315 airfoil at the root and N.A.C.A. 2309 airfoil at the tip with no twist. The N.A.C.A. 2309–2312–2315 series was selected because, on the average, it showed the smoothest shaped lift curve peaks of all the low cambered, low drag airfoils tested in the N.A.C.A. Variable Density Tunnel.[4] The stall of this wing was observed in flight, by wool tufts, to start at the leading edge near the right wing tip and progress rapidly to cover the whole tip portion of that wing, whereupon it would drop uncontrollably. The conditions with the split flaps extended were essentially the same as with them retracted.

Flight tests were then carried out with fixed auxiliary airfoils, 14.5% chord, extending over the outer 50% of the span. Two types were investigated, one with a symmetrical N.A.C.A. 0012 section and the other with a highly cambered N.A.C.A. 22 section.[5]

It was found that, under certain combinations of angles, these fixed auxiliaries improved the stalling characteristics by reducing the autorotational tendencies and improving the aileron control. The effects of these auxiliaries were quite insensitive to their angular setting; i.e., a large change in angular setting was necessary to bring about an appreciable change in the stall.

The cambered auxiliaries appeared to be better than the symmetrical in their effects on the stall. However, the installation of either type of auxiliary was so detrimental to the take-off and climb characteristics, particularly with the auxiliaries at the angles necessary for the best stall characteristics, that the use of the fixed auxiliaries could not be considered satisfactory and was, therefore, abandoned.

The other course which was followed to improve the stalling characteristics was to modify the airfoil sections on the outer portions of the wing by fairing out the under side of the leading edge in successive steps, increasing the leading edge radius, and increasing the airfoil camber. This procedure was found definitely to improve the stalling characteristics. With the final configuration, the CW-19 airfoil (Fig. 13) at the tip tapered to the N.A.C.A. 2315 airfoil at the root, all autorotational tendencies below the stall were eliminated and the airplane could be positively controlled in the stalled condition. The wool tufts showed that the stall of this wing started along the trailing edge near the mid point of the semi-span and proceeded gradually in all directions. The leading edge at the tip remained unstalled throughout. It is interesting to note that when the nature of the stall was changed so that the separation started at the trailing edge, instead of at the leading edge, the whole character of the stall became smooth, more controllable.

It appeared that the change to the CW-19 airfoil at the tip was equal in effectiveness at the stall to the

[4] Jacobs, Ward and Pinkerton, *The Characteristics of 78 Related Airfoil Sections from Tests in the Variable Density Wind Tunnel, N.A.C.A. Tech. Report 460,* 1933.

[5] Fred E. Weick & Robert Sanders, *Wind Tunnel Tests on Combinations of a Wing with Fixed Auxiliary Surfaces Having Various Chords and Profiles, N.A.C.A. Tech. Report 472,* 1933.

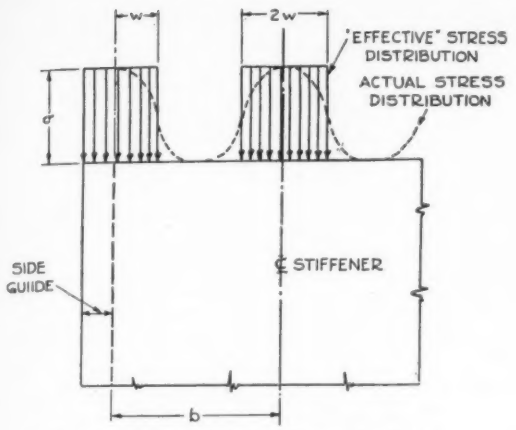


FIG. 12. STRESS DISTRIBUTION.

installation of either type of fixed auxiliary airfoil. There was no observable adverse effect on the stability or performance due to this modification.

Theoretical Investigation of Tapered Twisted Wings

One method of improving stalling characteristics of a wing is to use aerodynamic twist reducing the incidence along the span so that the tip will stall at a higher angle of attack than the root. The effects of this twist can be determined analytically by the method developed by Glauert.[6] (Chapter XI.) The circulation about any point on the wing span is expressed by the Fourier series

$$\Gamma = 2bV\Sigma A_n \sin n\theta \qquad (1)$$

where

Γ is circulation ($= C_L c\, V/2$)

b is wing span

c is wing chord at any point

V is velocity at infinite distance from wing.

θ represents point on wing span defined by the equation:

$y = (b/2) \cos \theta$

y is distance out from center line.

The downwash velocity w at any point θ becomes

$$w = V\Sigma n A_n \sin n\theta / \sin\theta \qquad (2)$$

By equating the circulation defined by the basic series (Eq. 1) to the circulation derived from the angle of attack as affected by downwash (Eq. 2), and assuming a straight line variation of lift coefficient with angle of attack, the following equation is obtained for the tapered wing with constant twist along the span:

$$\Sigma A_n \sin n\theta [n/\sin\theta + 1/\mu] = \bar{\alpha} - (\cos\theta)\,\epsilon \qquad (3)$$

where

$\mu = (c/4b)(dC_L/d\alpha_o)$

$\bar{\alpha}$ is absolute angle of attack at the root measured from zero lift

ϵ is aerodynamic twist at tip (positive when the angle of attack is less at the tip than at root.)

The first four coefficients of the series A_1, A_3, A_5, and A_7 can be evaluated by satisfying Eq. (3) at the four points $\theta = 22\frac{1}{2}°$, 45°, $67\frac{1}{2}°$, 90°. This evaluation has been made for a straight tapered wing as follows:

Aspect Ratio $R = b^2/S = 6.724$

Tip Chord/Root Chord = .461

$dC_L/d\alpha_o = 5.84$ / radian

$$\begin{aligned} A_1 &= .21543\,\bar{\alpha} - .08832\,\epsilon \\ A_3 &= .00474\,\bar{\alpha} - .04585\,\epsilon \\ A_5 &= .00963\,\bar{\alpha} + .00362\,\epsilon \\ A_7 &= -.00087\,\bar{\alpha} - .00613\,\epsilon \end{aligned} \qquad (4)$$

The total lift of an airfoil is (by page 136, Ref. 6)

$$L = \tfrac{1}{2}\pi b^2 \rho V^2 A_1$$

when the average lift coefficient is

$$C_{Lav.} = 2L/S\rho V^2 = \pi b^2 A_1/S = \pi R A_1 \qquad (5)$$

It is now convenient to evaluate the coefficients in terms of $C_{Lav.}$ and ϵ, which become:

$$\begin{aligned} A_1 &= .04734\,C_{Lav.} \\ A_3 &= .00104\,C_{Lav.} - .04391\,\epsilon \\ A_5 &= .00212\,C_{Lav.} + .00757\,\epsilon \\ A_7 &= -.000191\,C_{Lav.} - .00649\,\epsilon \end{aligned} \qquad (6)$$

The induced drag of the airfoil is (by page 140, Ref. 6)

$$D_i = \tfrac{1}{2}\pi b^2 \rho V^2 \Sigma n A_n^2$$

whence

$$C_{Di} = \pi R \Sigma n A_n^2 \qquad (7)$$

Substituting the coefficients, the induced drag coefficient of the wing becomes

$$C_{Di} = .04788\,C_{L^2av.} - .00199\,C_{Lav.}\,\epsilon + .1333\,\epsilon^2 \qquad (8)$$

and the increase in drag coefficient $\Delta C_{Di} (= C_{Di} - C_L^2/\pi R)$ over that for an elliptical lift distribution becomes:

$$\Delta C_{Di} = .00054\,C_{L^2av.} - .00199\,C_{Lav.}\,\epsilon + .1333\,\epsilon^2 \qquad (9)$$

(ϵ expressed in radians throughout)

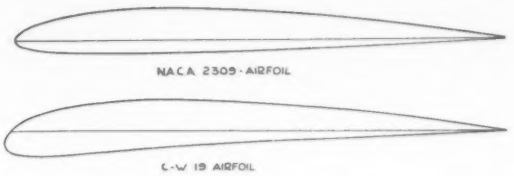


FIG. 13.

[6] Glauert, *Airfoil and Airscrew Theory*, Cambridge Press, London.

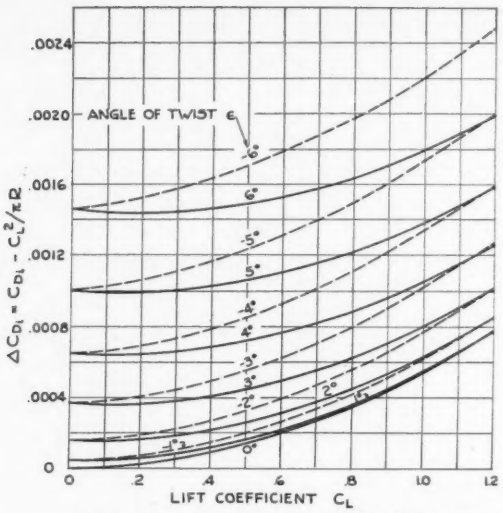


FIG. 14. ΔC_{Di} FOR TAPERED WING.
ASPECT RATIO = 6.724 $dC_L/d\alpha_0 = 5.84$/rad.
TIP CHORD = .461 ROOT CHORD.

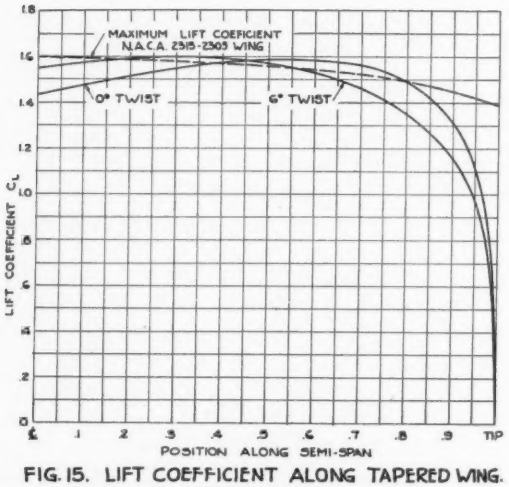


FIG. 15. LIFT COEFFICIENT ALONG TAPERED WING.
$C_{L_{AV.}} = 1.50$
ASPECT RATIO = 6.724 TIP CHORD = .461 ROOT CHORD.

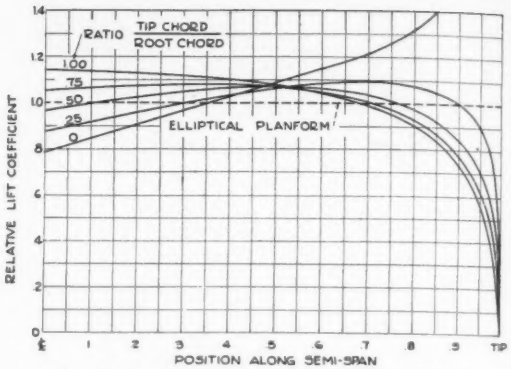


FIG.16 LIFT COEFFICIENT GRADING CURVES.
TAPERED WINGS A.R. = $dC_L/d\alpha_0 = 5.8$

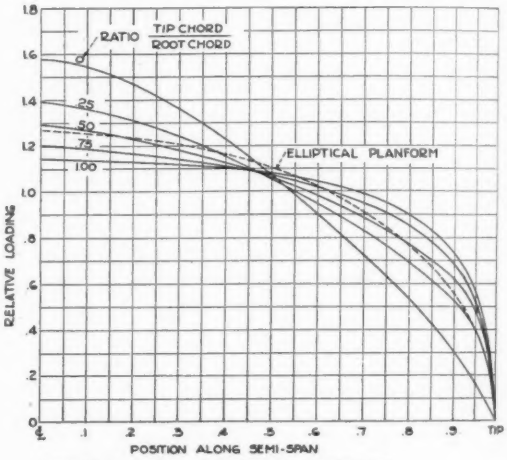


FIG.17. LOAD GRADING CURVES.
TAPERED WINGS. A.R. = $dC_L/d\alpha_0 = 5.8$

Curves are plotted in Fig. 14 giving the values of ΔC_{Di} for various angles of twist. For a twist up to 2° the induced drag is not serious, amounting to not over 1% of the drag of an average airplane, but as the twist is increased above 2° the drag becomes appreciable.

The lift coefficient at any one of the four points $\theta = 22\frac{1}{2}°$, 45°, $67\frac{1}{2}°$ and 90° is obtained from Eq. (1) to be:

$$C_L = 2\Gamma/cV = (4b/c)\Sigma A_n \sin n\theta \qquad (10)$$

In Fig. 15 are plotted the lift coefficients along the span of this wing with zero twist and a wing with a hypothetical 6° of twist, both at $C_{Lav.} = 1.50$. In this figure is plotted also a curve for the maximum lift coefficient along the span which was developed taking into account the variation in the maximum lift with airfoil thickness ratio and with Reynolds Number, which varies along the span due to the taper.

It is seen that the wing with 0° twist exceeds the maximum lift coefficient for the 2315–2309 series over a considerable portion of the outer wing, and it is therefore reasonable that there should be a pronounced tendency to stall at the tip first, bringing about uncontrollable autorotation. The curve with 6° twist represents a wing that should be satisfactory in the stall if the N.A.C.A. 2315 to 2309 wing were retained. However, referring again to Fig. 14 it is seen that such a wing would have an appreciably higher drag than the untwisted one. It is to be concluded, therefore, that to try to obtain good stalling characteristics merely by twisting the wing is decidedly inefficient. It is much better to use only 1°–2° of aerodynamic twist in combination with a tip airfoil having a high value of C_{Lmax} and having a lift curve with a round smooth top.

It is of interest to note that the benefits gained by substituting the CW-19 airfoil for the N.A.C.A. 2309

airfoil at the tip were due entirely to the extension of the lift curve to a high value of C_{Lmax} at a high angle of attack. There was only 0.2° shift of the zero lift angle from the N.A.C.A. 2309 airfoil to the CW-19 airfoil referred to a common chord as determined by tests in the Buffalo wind tunnel of the Curtiss Aeroplane and Motor Company. However, these tests on 10″ x 60″ airfoils at 80 m.p.h. showed that the CW-19 airfoil developed a high uncorrected $C_{Lmax.} = 1.36$ with a smooth, rounded lift curve peak, comparable to $C_{lmax.}$ $= 1.00$ for the N.A.C.A. 2309 and $C_{Lmax} = 1.18$ for the Clark Y.

Figs. 16 and 17 have been prepared using coefficients from Reference 6 to show the load grading curves and lift coefficient grading curves for a series of airfoils with various taper ratios for an aspect ratio $R = d\,C_L/d\alpha_0 =$ approximately 5.8. It is important to recognize that while structural efficiency is gained with the high taper ratios, the problems of obtaining good stalling characteristics are increased.

A Note on Fuselages of Low Drag

JOHN R. MARKHAM and SHATSWELL OBER, *Massachusetts Institute of Technology*

(Received April 11, 1936)

THIS note represents some results of a study of fuselage drag made by the Aeronautical Laboratory staff at the Massachusetts Institute of Technology in cooperation with the United Aircraft Manufacturing Corporation. The object was to see whether it was necessary for the fuselage drag of a large transport plane to exceed materially that of an airship form. When considering the results one must remember that the full size fuselage will be well over 10 feet in diameter at the largest part so that an adequate windshield need extend only a small amount above the smooth contour. If the models were of a smaller fuselage the windshields provided would be inadequate.

The width and height of the fuselage for a transport plane are fixed by the arrangement of passengers or cargo. The length is determined by the general aerodynamic design of the airplane. The fineness ratio, which may be defined exactly as the ratio of the length to the diameter of a circle of area equal to the maximum cross section of the fuselage, will usually be much greater than the ideal for the minimum drag, and greater than now used for airship hulls. With a fixed cross section, minimum drag would be obtained by using the shortest shape which avoided separation of flow from the tail. Any increase in length increases the drag since the surface is increased and from tests the fineness ratio giving the least drag for a fixed cross-sectional area is about 3. Airplane fuselages will have fineness ratios of from 7 to 9, and therefore must have appreciably higher drag coefficients than an ideal streamlined body, even though a perfectly symmetrical airship shape could be used.

To provide a basis for comparison, the first model for this study was made of an airship shape stretched longitudinally so that the fineness ratio was 7:3. This model had circular cross sections throughout and a pointed tail. It will be called the "airship model." (Model I)

The first modification was to droop the nose, a start toward provision of a pilot's cabin, and to raise and deepen the tail. The principal sections were still circular. (Model II)

The next change was to add a cabin and windshield providing sufficient outlook for the pilots. The windshield is conical, while the cabin roof is rounded and both fair smoothly into the surface of the fuselage. (Model III)

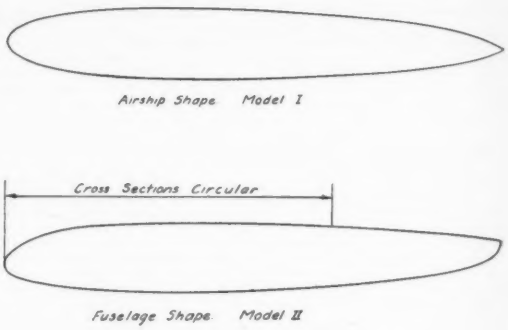


Fig. 1. Outline of Models

This cabin added so little to the drag of the fuselage that another with somewhat higher windshield and flatter roof was built. The windshield was cylindrical in front and twisted at the sides to fair into the fuselage. The corner between windshield and roof was sharp. (Model IV)

All of the models were made of highly polished wood. The maximum cross section was 60.8 square inches, the length 64 inches. Tests, of the different fuselage models alone, were made in the 7½ foot tunnel at a Reynold's Number of 2,440,000 with two different degrees of turbulence in the initial stream. The turbulence was such that the smoother flow gave a critical Reynold's Number for a sphere of 186,000, while with a grid of rods inserted the critical Reynold's Number dropped to 117,000. The models were mounted on a transverse rod located somewhat forward of the center of gravity with a wire near the tail. Tare drag was found by duplication.

Results of the tests in the smoother stream indicated that there was sufficient laminar flow in the boundary layer to make them unreliable. Relatively slight changes in shape apparently caused changes in the transition phenomena so that the drag differences were unduly large. Tests of the effects of a wire around the nose showed the increase in drag characteristic of changing the boundary layer from partially laminar flow to turbulent flow. The results of the tests in the smoother stream are presented merely as a warning, particularly against hasty judgment of windshield drag. On a flat surface in a smooth stream the boundary would be laminar for a distance about 1/5 the length of these models. Two factors would tend to change this

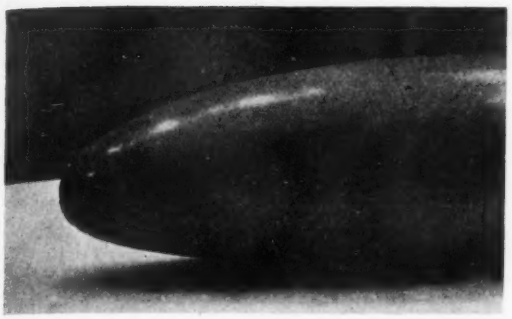


Fig. 2. Fuselage nose—without windshield. (Model II)

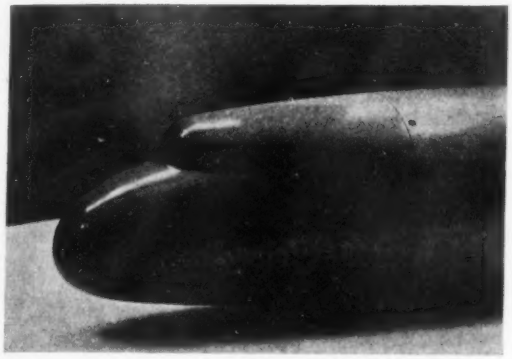


Fig. 3. Fuselage nose—with conical windshield. (Model III)

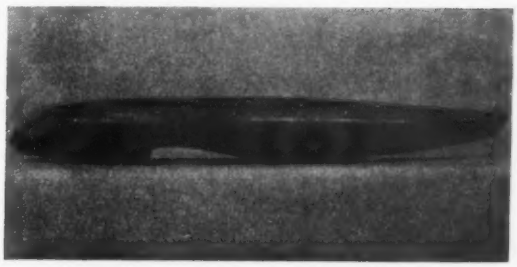


Fig. 4. Side view of fuselage with conical windshield (Model III). Cutout for wing made after drag tests were completed.

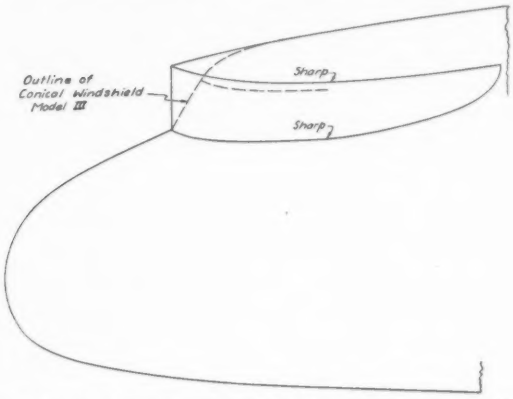


Fig. 5. Vertical front—cylindrical windshield. (Model IV)

length; the initial turbulence would shorten it and the reduction in pressure along the surface extend it further back. No velocity measurements to determine the transition point were made.

The results of the tests are given by the Table I.

TABLE I

Angle of Attack 0°, R. N. 2,440,000

Initial Stream	Smoother	More Turbulent
Critical R. N. for sphere	186,000	117,000
Drag Coefficients:		
Model I—Airship Shape	.072	.099
Model II—Fuselage without windshield	.085	.103
Model III—with conical windshield	.097	.104
Model IV—with cylindrical windshield.	.113	.117

Drag coefficients are based on the projected area and the dynamic pressure. "L" in the Reynold's Number is the length along the axis of the models.

A lower limit of the friction drag on an airship may be estimated by considering the surface replaced by a cylindrical projection, assuming the velocity to be that of the airship and the coefficient of friction that of a flat plate with turbulent boundary layer. A friction drag coefficient based on the projected area may be estimated by multiplying the coefficient of friction by the ratio of the surface area to the cross sectional area. For Model I, airship model, this area ratio is 23, the coefficient of friction, C_F, at a Reynold's Number of 2,440,000 for a flat plate with turbulent boundary layer is .0039, so the corresponding C_D is .090. The measured C_D was .099—the difference being due to the calculation of friction drag from airship speed instead of local air speed or, to a slight degree, to pressure drag.

If the airship model drag is assumed to be all friction, and the ratio between the effective C_F and the flat plate C_F to remain constant, the airship coefficient at any Reynold's Number may be estimated from the variation of turbulent friction drag with Reynold's Number. The drag coefficient of the other models may be assumed to remain greater by a constant amount than that of the airship. For example, at a Reynold's Number of 180,000,000, not unlikely to be reached by a large plane, C_F for the flat plate is .0020, C_D for the airship would be estimated to be .052, for the fuselage with the conical windshield .057, and for the fuselage with the cylindrical windshield .070.

A satisfactory pilot's cabin and windshield, together with the changes in shape of the back of the fuselage, increases the full scale drag coefficient over that of an airship form by only 10%. This small increase over the airship drag can only be realized if every care is taken to maintain the skin smooth and unbroken. There may be no miscellaneous protuberances. Windows must be flush. The test data and the method used for estimating the full scale drag coefficients make no allowance for the effect of such disturbances. This discussion refers to drag of the fuselage alone without consideration of interference, which will be reported in a future note.

Propeller Design As Applied to Windmills

E. N. FALES, *Wright Field*

(Received April 24, 1936)

THE application of propeller design to windmill construction was familiar on aircraft in the years following the war. Various camera mechanisms, gasoline pumps, and electric generators were driven by 2 or 4 blade windmills of 18 inch diameter and less, deriving their power from the motion of the aircraft.

More recently, wind driven electric generators of advanced design and larger size, up to 20 feet in diameter, have appeared on the market, capable of using natural winds and developing 2 kw. or less. For example, such a generator of 1.5 kw. capacity was used in the Byrd Antarctic Expedition of 1933–35, where it saved about a thousand gallons of gasoline.

During the past year about 70,000 small 6-volt wind-driven generators have been sold in connection with the radio industry. By their aid the radio market has been broadened to include remote farms and other regions where no previous source of current was available to operate receiving sets. The generating system is similar to that of an automobile, except that the generator is mounted on a short tower on the house-top, instead of on the engine; it is connected to the radio battery by wires, and an automatic cut out such as used on automobiles prevents reverse flow of the battery current when the windmill is not turning, (See Fig. 1).

Automobile generators are used, for they offer the happy combination of cheap production with just the right r.p.m. and power characteristics to permit direct gearless drive; and the propellers are therefore mounted directly on the armature shaft. The units thus simplified have successfully retailed at prices from $15 to $50.

These and other direct-drive units are successful in regions of ample wind. For calmer regions, such as the middle west, larger propellers must be used, with step-up gearing, in order that adequate current be produced.

The correct relation between size of propeller, r.p.m., and generator capacity to match the wind conditions of various regions may be calculated without resort to cut-and-try methods. The fundamental principles governing windmill design may be reviewed as follows:

(1) It is theoretically impossible in an open-air windmill to recover more than 59% of the kinetic energy contained in the wind.

(2) If the windmill is 75% efficient, and the generator 60%, 27% of the kinetic energy of the wind may be converted into electricity.

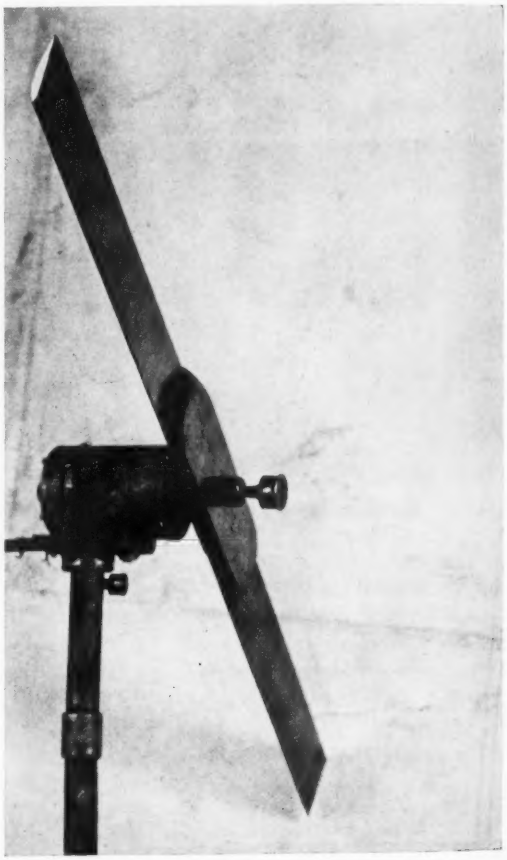


FIG. 1. Small direct-drive 6 volt wind-driven electric generator.

(3) The amount of energy captured from the wind by a windmill depends on the amount of wind intercepted, that is, on the disk-area swept by the blades. A well designed windmill is one which, irrespective of the number of blades, decelerates the whole horizontal column of air to ⅓ its free velocity. In this case the power is not primarily determined by the number of blades; for the wind can be "stopped" by a 20-blade mill or by a single blade mill.

(4) Whatever type of windmill is used, the energy taken from the wind varies as the cube of the wind velocity. For example, 8 times as much power can be taken from a 20 m.p.h. wind as from a 10 m.p.h. wind.

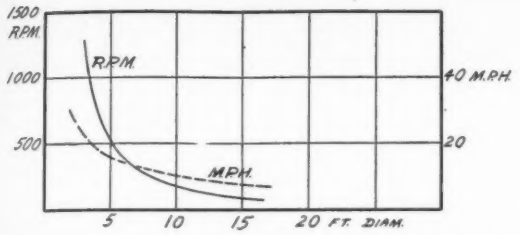


FIG. 2. Relation between diameter and r.p.m. and wind velocity in a series of propeller windmills, all having the same power, (.22 h.p. for radio generator drive).

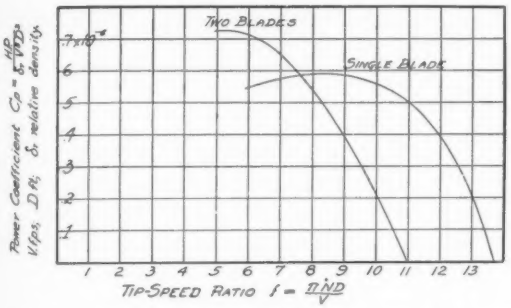


FIG. 3. Power developed by propeller type windmills.

(5) The r.p.m. varies inversely as the diameter, but in a windmill of given diameter the r.p.m. depends on the pitch and number of blades.

RELATION BETWEEN SIZE OF PROPELLER AND WIND

In general, the diameter and gearing varies inversely with the 3/2 power of the wind speed; that is, if a windmill which operates successfully in a 20 m.p.h. wind is to operate equally successfully in a 10 m.p.h. wind, its diameter must be increased $(20/10)^{3/2}$ or 2.87 times.

Fig. 2 represents an imaginary series of windmills of differing diameters and gear-ratios, all designed to produce the same power, (0.224 h.p. for a radio generator). As an example, a 5½-ft. propeller will operate the generator in a 15 m.p.h. wind; but if results are wanted in a 10 m.p.h. wind, the diameter must be increased to 10 feet, and the gearing altered accordingly.

POWER AND R.P.M. OF PROPELLER WINDMILLS

Fig. 3 gives the coefficients needed to predict the operating characteristics of a propeller-type windmill. The data was secured in the wind tunnel, using accurately made models 24 inches in diameter, and relates to a design having the proper pitch and blade-width requisite for maximum power. Given the wind velocity in feet per second, and diameter in feet, and the relative density of δ_r expressed as a fraction of standard air density, the power obtainable follows from the formula

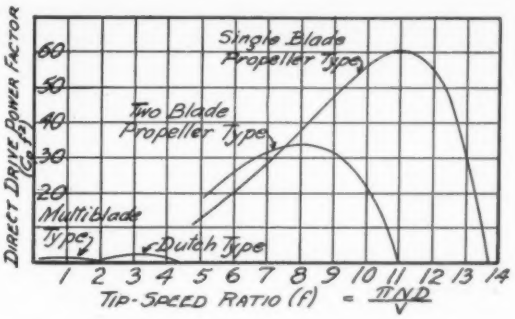


FIG. 4. Direct-drive power factor, showing superiority of high tip speed for direct-drive installations.

$$\text{h.p.} = C_p \times 10^{-6}\ \delta_r \times D^2 \times V^3$$

The r.p.m. follows from the formula

$$\text{r.p.m.} = 60 \times (f) \times V/\pi D$$

The gear ratio will be chosen to match this r.p.m. to any desired generator.

The outstanding characteristic of the propeller-windmill is the fact that in a given wind it rotates 5 to 10 times faster than a conventional windmill of the same size. While the power is slightly greater, this is not a vital feature because inefficiency may always be overcome by a little extra diameter. Compared to a multiblade windmill, the torque is smaller in proportion as the r.p.m. is greater; and the propeller-type excels in lightness of construction and reduction of gear difficulty. It is the only type of windmill by which direct generator drive can be accomplished.

Fig. 4 shows this superiority in direct drive. In this diagram the tip-speed-ratio "f" is plotted against the "Direct Drive Factor" $(C_p f^2)$ which represents the power obtainable from windmills mounted on the armature shaft of a fixed r.p.m. generator, the wind being the same throughout. The 4 curves show the large spread between conventional and propeller type windmills. The single-blade mill can be built in large diameter and still rotate up to specified speed, and thus can deliver 100 times more power than the multiblade. The 2-bladed propeller gives 56 times more power than the smaller multiblade; and the Dutch type is hardly out of the multiblade range, giving only 3½ times more power. Note that in this application, high rotary speed is of vital importance, because it makes possible use of larger diameter, therefore larger power, on a gearless armature shaft.

Fig. 5 shows a single-blade windmill swinging a 20 ft. diameter circle. It "stops" the wind as well as does a multiblade. The merit of this type is that bending stresses at the hub are reduced by ⅔; the regulating mechanism is simplified because there is only one blade to be regulated; and, last but not least, the cost of production does not rise much as the

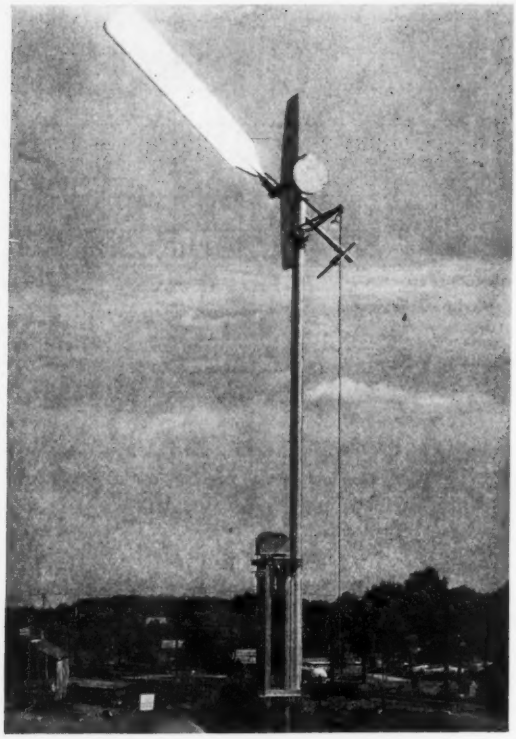


FIG. 5. Twenty-foot diameter wind-driven generator with single articulated blade.

diameter is increased. For example, if diameter is increased from 20-feet to 30-feet, the power increases 2¼ times at a cost of only 17 additional square feet of blade area; whereas, in the case of a 30-foot multi-blade mill the weight and cost are prohibitive. By means of the light, single-blade, pitch-regulated windmill of large diameter, farmers may have 5 or 10 times more power than is now available in conventional windmills, at an added expense that is small compared to the convenience of farm-electrification.

In the larger diameters, 20 to 50 feet, regulation of r.p.m. is mandatory for prevention of overload when excessive winds arise. Any other method than pitch-change is difficult; the older method of swinging out of the wind induces gyroscopic vibration, and eliminates the power supply at the very time when the best winds are blowing. Lift-destroyers and air-brakes are undesirable, as they throw heavy loads on the structure. (For example, a 20-ft. windmill which gives 2 h.p. in a 15 m.p.h. wind would have to "spill" 14 h.p. through air-brake regulation in a 40 m.p.h. wind.) On the other hand, pitch-regulation holds the energy absorption nearly constant at all wind velocities, and allows continuous power output in high winds, without undue stresses; in the same way that a glider has the same lift at all speeds.

The single-blade windmill in Fig. 5 derives its pitch changing moment from the torque of its counterbalance bar, which lies skew-wise to the plane of rotation, held by a spring until excessive r.p.m. causes the skew-bar to turn toward the plane of rotation, carrying with it the blade which is on the other end of the spar. Note that in the particular design illustrated, the tubular spar extends from the blade, through the hub, to the counterweight. This eliminates centrifugal loads completely from the hub, and no bearing stresses arise other than those necessary to transmit the torque. For the sake of running balance, articulation is provided for the whole propeller, in the manner of an autogiro blade, enabling the resultant force to lie all the time along the shaft axis. The articulation is a feature not used in the little single-blade aircraft windmills, whose ratio of thrust to centrifugal force is small.

DISTRIBUTION OF WINDS IN THE UNITED STATES

The relative wind velocity prevailing in any location determines what type of windmill generator is best suited to that region. A direct-drive generator may be quite successful in the windy regions of Nebraska, but unsatisfactory in Ohio. Therefore a manufacturer may offer several types, each suited to one locality only. Below are tabulated relative wind velocities existing in various parts of the U. S. The figures are average velocities for a year's time as recorded by the Weather Bureau, and as they stand, offer a comparative indication of where the market for windmills is to be found. They are not to be used as design velocities; but after analysis may be so used to determine the size of windmills suited to each locality.

Table I indicates regions having annual average velocities 10 m.p.h. or higher. Note that a 10 m.p.h. average wind is made up of many low winds and a few high winds. Six m.p.h. is the lowest wind for practical use; 12 to 25 m.p.h. is the range of the higher winds affording good power.

TABLE I

High Wind Regions Having 10 m.p.h. or More Average Yearly Wind Velocity

(From U. S. Dept. of Agriculture Yearbook, 1911)

A north and south strip 350 miles wide midway between the Atlantic and Pacific Oceans comprising:

Minnesota	Northern Half.
North Dakota...	Western Half 10 m.p.h.; Eastern Half, 12 m.p.h.
South Dakota...	Western Half 10 m.p.h.; Eastern Half, 12 m.p.h.
Nebraska	12 m.p.h. between N. Platte and Pierre, S. Dakota.
Kansas	10 m.p.h. Central region; 12 m.p.h. Western Half.
Oklahoma	10 m.p.h. Central Region; 12 m.p.h. Western Half.
Texas	10 m.p.h. East of the Pecos River; 12 m.p.h. North of Abilene; 14 m.p.h. in the Amarillo region.

The littoral of the Great Lakes, Atlantic Seaboard, and Gulf Coast, and the Pacific near San Francisco, and at Washington State.

Exceptionally high wind regions include Point Reyes, California; the Washington and Texas Coast lines; Northern Texas; Duluth, Minn.; Cape Hatteras and Cape Cod.

FIG. 6. Twenty-foot windmill test-car.

ANALYSIS OF THE WINDS

In regions other than those tabulated, special design is recommended for windmills. To find the relation between wind and windmill characteristics, a detailed study has been made of wind records at Dayton, Ohio, covering 7 years. It is found that in each month two groups of winds exist. First, there are the frequent, prevalent winds ranging from 5 to 13 m.p.h. Then there are the "Energy Winds," blowing less frequently, ranging from 13 to 23 m.p.h.

The prevalent winds blow 2½ times more often than the more vigorous "Energy Winds," say 5 days out of an average week as against 2 days for the "Energy Winds," but due to the fact that the energy varies with the cube of the velocity the "Energy Winds," when they do blow, produce ¾ of the total power contained in the wind. A windmill to utilize the prevalent winds must be twice the diameter of a windmill running only on the energy winds, if each is to produce the same amount of electricity per month.

The curves of Fig. 7 record the general results obtained from the above mentioned study of Dayton Winds, and indicate the following facts:

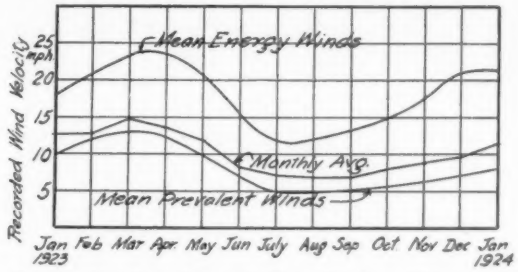


FIG. 7. Hourly wind velocities, Dayton, Ohio, 1923. The curves represent averages of 13 "frequency" and "energy" charts compiled from Weather-Bureau records.

(1) The mean prevalent velocity for any month may be estimated if the mean average hourly velocity is known, being about 2 m.p.h. less than the average hourly velocity for the month.

(2) The prevalent winds have velocities about 43 per cent as great as the energy winds.

Detailed analysis of the records also show that the actual energy content of natural wind in any month, including the energy of the low winds and of the high winds, adds up to double what would be computed from the average hourly velocity for that month. This is due to gustiness; and a steady wind to give the same power as this gusty wind would have to blow 1.27 times as fast as the recorded average wind.

Appraisement of the future commercial significance of wind power depends on such wind analysis. The wind-driven generators now on the market are relatively small units, relying on the "Energy Winds," and require auxiliary storage batteries to tide over days when only mild winds are stirring; the propellers are usually less than 16 feet in diameter.

Future commercialization will expand when sizes twice as great as the present windmills are on the market, for by these the prevalent winds become available; and storage battery expense, the main item in a wind power plant, will be reduced because there will on the average be only 2 calm days per week, instead of 5.

Distribution of Heat Loss to the Jackets in an Internal Combustion Engine Cylinder

C. FAYETTE TAYLOR, *Massachusetts Institute of Technology*

(Received May 7, 1936)

Introduction

IN spite of a large amount of research work which has been conducted in the general field of the direct heat losses of internal combustion engines, little seems to have been published with regard to the distribution of the heat flow between the various parts of the cylinder structure. Since data on this particular subject should be useful in design, an investigation in this field has been performed in the automotive laboratories of the Massachusetts Institute of Technology and is the subject of this paper.

The work was done under the direction of E. S. Taylor and the author, by Cummings, Lyon, Goldberg and Goldstein, whose cooperation is gratefully acknowledged.

Apparatus

The cylinder selected for this work was from a Liberty 12, water-cooled airplane engine. The standard cylinder was altered so as to separate the jacket spaces surrounding the cylinder barrel, the cylinder head and the exhaust port. Fig. 1 is a sectional view showing how these changes were effected. The exhaust-port jacket was separated from the cylinder-head jacket by autogeneous welding. The cylinder-head jacket and cylinder-barrel jacket were separated by cutting a circumferential slot around the outer jacket wall in the plane of the top of the piston at top center. A section of automobile inner tubing was placed over the slot so formed, and drawn in against the cylinder wall by a wire wrapping. Each of the three jacket sections thus formed was equipped with a water-inlet connection at the bottom and a water-outlet connection at the top, as shown in the figure.

The cylinder was mounted on a universal crankcase which provided a stroke of 5½ in. A standard Liberty piston was used, together with a special connecting rod which permitted adjustment of the compression ratio. Valves were operated by a push-rod gear. The unit thus formed was connected to an electric cradle-type dynamometer with all the usual instruments for measuring power, fuel consumption, temperature, pressures, etc.

Each of the three jacket spaces of the cylinder was provided with a separate water circulation system. The arrangement used is shown in Fig. 2. Each system forms a separate circuit, including a passage connecting the inlet and outlet, a nozzle for inducing circulation and for introducing cold make-up water from the city lines, and an overflow at the top of the system. In the case of the barrel and head jackets,

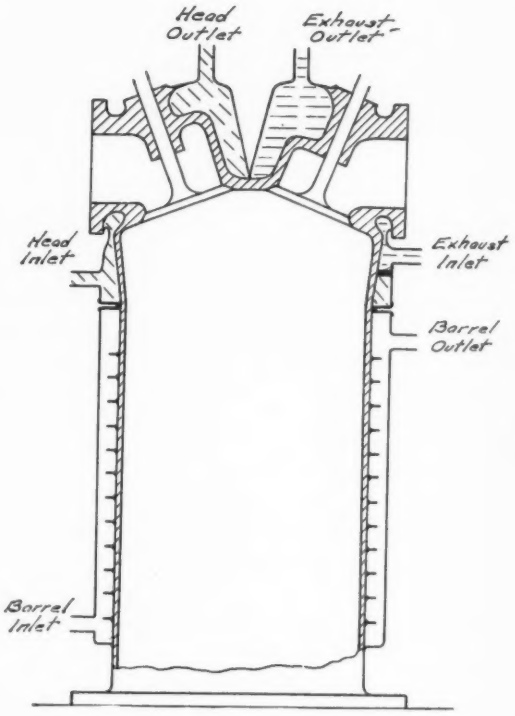


Fig. 1 - Section of Cylinder

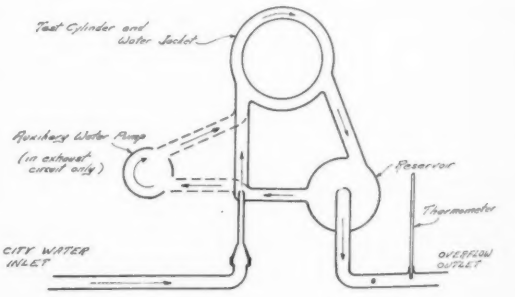


Fig. 2 - Circulation System

TABLE I
COMPRESSION RATIO 4.00

Run No.	r. p. m.	b. hp.	B. S. F. C. lbs./ hp./hr.	Friction hp.	lb. fuel/ hr.	Spark advance, degrees	B. t. u. per minute		
							Head	Barrel	Exhaust Port
1	1000	12.1	1.06	2.5	12.8	30	236	167	92
2	"	12.7	.88	"	11.2	"	268	185	103
3	"	12.8	.79	"	10.1	"	290	195	107
4	"	12.9	.74	"	9.5	"	296	200	111
5	"	12.8	.67	"	8.6	"	305	204	118
6	"	12.2	.66	"	8.0	"	298	186	125
7	"	10.9	.68	"	7.8	"	272	195	118
8	1300	14.2	1.15	4.5	16.3	30	262	187	122
9	"	15.1	.89	"	13.5	"	305	204	132
10	"	15.3	.78	"	12.0	"	327	212	142
11	"	15.6	.77	"	12.0	"	332	217	141
12	"	15.1	.72	"	10.9	"	342	225	148
13	"	13.9	.70	"	9.8	"	326	220	151
14	1600	17.4	1.09	5.8	19.0	30	313	205	149
15	"	18.3	.88	"	16.1	"	358	225	164
16	"	18.4	.79	"	14.5	"	381	236	179
17	"	17.7	.70	"	12.3	"	385	238	1 0
18	"	17.2	.68	"	11.7	"	383	239	192
19	"	12.8	.81	"	10.4	"	311	211	182
20	"	.....	.....	"	.....	"	.....	.....	.....
21	1000	13.1	.74	2.5	9.7	35	315	202	119
22	"	13.0	.74	"	9.6	30	302	193	120
23	"	12.9	.75	"	9.7	25	296	195	121
24	1300	15.8	.74	4.5	11.7	35	344	222	142
25	"	15.6	.77	"	12.0	30	332	217	141
26	"	15.1	.78	"	11.7	25	326	216	148
27	1600	18.3	.72	5.8	13.1	35	384	244	181
28	.....	18.0	.71	"	12.8	30	376	245	189
29	.....	17.5	.71	"	12.4	25	370	241	183
			Compression Ratio - 4.58						
30	1000	13.9	.87	2.6	12.1	30	264	140	82
31	"	14.0	.78	"	10.9	"	268	155	90
32	"	14.2	.68	"	9.7	"	293	166	100
33	"	14.2	.59	"	8.3	"	305	172	113
34	"	13.2	.58	"	7.6	"	278	160	110
35	1300	17.5	1.1	4.3	19.2	30	243	219	102
36	"	17.8	.77	"	13.6	"	345	200	125
37	"	18.3	.69	"	12.6	"	361	210	133
38	"	18.5	.65	"	12.0	"	364	218	134
39	"	17.6	.61	"	10.8	"	354	221.	142
40	"	16.2	.59	"	9.6	"	308	188	135
41	1600	19.5	.98	6.2	19.0	30	294	194	123
42	"	20.1	.80	"	16.0	"	353	224	144
43	"	20.3	.75	"	15.3	"	364	229	147
44	"	20.5	.72	"	14.7	"	369	231	147
45	"	20.2	.67	"	13.6	"	383	205	172
46	"	19.2	.61	"	11.7	"	366	199	176
47	"	13.7	.76	"	10.4	"	283	170	171
48	1000	14.1	.66	2.6	9.3	35	333	173	99
49	"	14.4	.67	"	9.7	30	323	166	112
50	"	14.3	.67	"	9.6	25	309	165	121
51	1300	19.0	.61	4.3	11.6	35	369	194	142
52	"	18.9	.61	"	11.5	30	354	188	142
53	"	18.7	.62	"	11.5	25	348	188	144
54	1600	20.5	.74	6.2	15.1	35	394	193	171
55	"	20.5	.74	"	15.2	30	385	197	178
56	"	19.7	.77	"	15.2	25	364	195	182

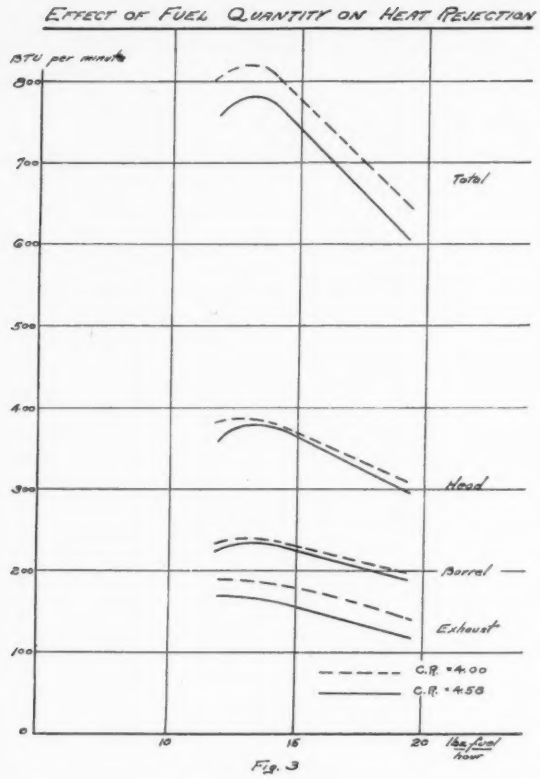


Fig. 3

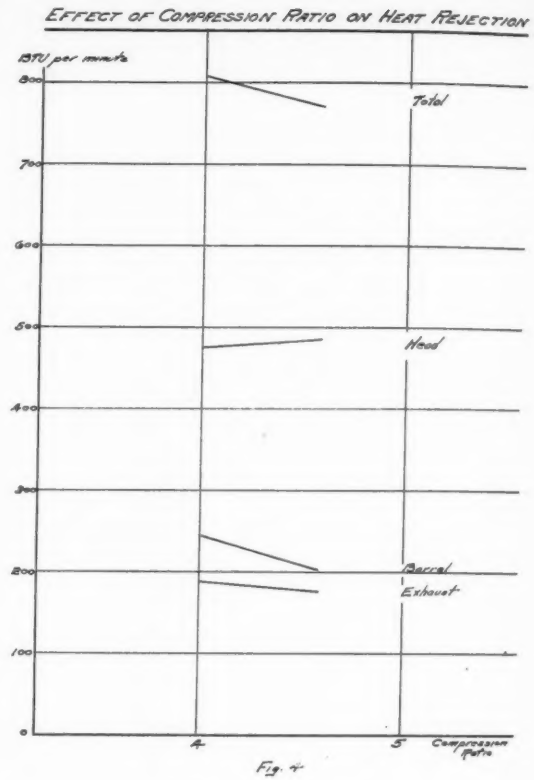


Fig. 4

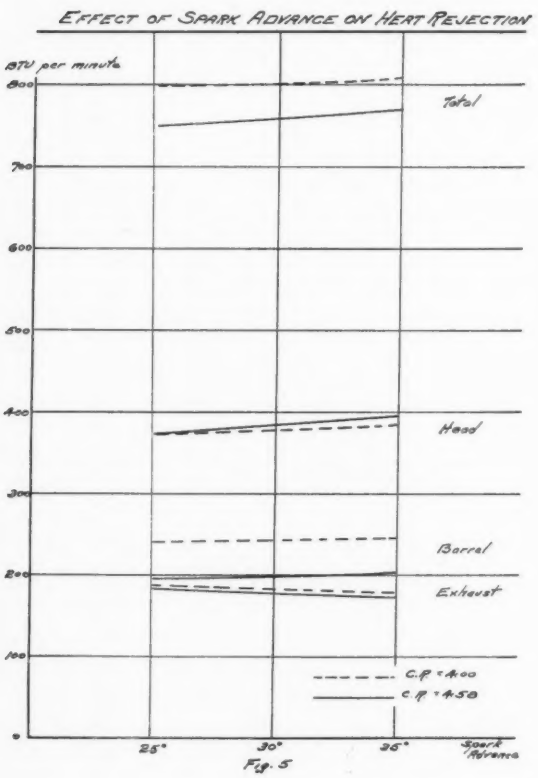


Fig. 5

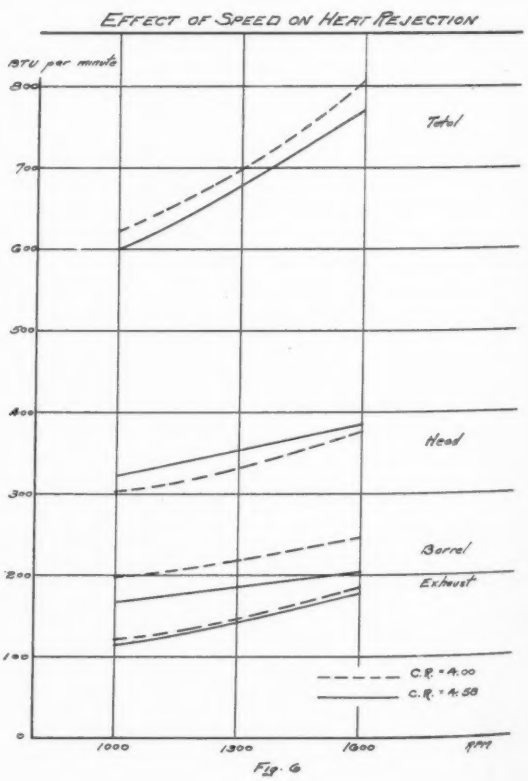


Fig. 6

TABLE II

ESTIMATE OF RELATIVE HEAT LOSSES TO VARIOUS PARTS OF THE JACKET
(Based on compression ratio of 4.3)

	Per cent Total Area	Per cent Time of Exposure	Relative Density				Estimated Average △T, °F.				Per Cent of Heat Loss	
			Inlet	Comp.	Exp.	Exh.	Inlet	Comp.	Exp.	Exh.	Est.	Meas.
Barrel..	53	50	1	2.6	2.6	1	−100	350	3500	2500	40	27 to 32
Head...	37	100	1	2.6	2.6	1	−100	350	3500	2500	56	50 to 55
Exhaust Port..	10	30	.....	.....	.....	1	.....	.....	.....	2500	4	17 to 22

The velocity factor is not included in this estimate, since no reliable basis is available. It is much higher in the case of the exhaust port than for the other parts, which probably accounts for a good deal of the discrepancy between the estimated and measured values.

circulation was maintained by the velocity of the make-up water as it issued from the nozzle. In the case of the exhaust-port jacket, it was found necessary to use a small water pump in the circuit. Glass thermometers were mounted in the cold-water supply pipe and in each overflow.

PROCEDURE

A series of runs was made at each of two compression ratios, 4.00 and 4.58. Performance and heat rejected to each of the jackets were measured at different engine speeds, fuel-air ratios and spark advances. The range covered by these variable is indicated by Table I.

Power output was computed from readings of r.p.m. and brake load. Fuel quantities were measured with a calibrated volume meter. Heat rejection to the various sections of the jacket was measured by weighing the overflow in a given time from each jacket system, and recording the difference in temperature between the make-up water entering the system and the overflow-water leaving the system. The overflow-water temperature was maintained as nearly as possible at 180° F. for all tests by adjustment of the flow of cold water into each system. Spark advance was measured by a spark protractor on the end of the dynamometer shaft.

In nearly every case, four complete sets of readings were made for each run. The results given in the tables and curves are the averages of such readings. The usual type of motoring friction run was made at the end of each day's tests.

RESULTS

From some earlier tests on a similar set-up where the inlet-port jacket was also isolated, it was found that the amount of heat absorbed or rejected from the inlet-port jacket was negligible. It was concluded, therefore, that the jacket water neither absorbed nor rejected heat from the inlet port and the heat rejected to the cylinder head should be considered accordingly.

Table I and Figs. 3, 4, 5, and 6 summarize the results of these tests. The relative amount of heat rejected to the three different jacket spaces remained within the following limits for all tests:

Cylinder head (including valve seats).....50–55%
Cylinder barrel 27–32%
Exhaust port 17–22%

ANALYSIS OF RESULTS

The heat loss to any section of the cylinder wall of an internal combustion engine should be a function of the following quantities:

ΔT, the average difference in temperature between the cylinder gases and the cylinder walls,

ρ, the average density of the gases,

V, the average velocity of the gases with reference to the cylinder wall.

The trend shown by the various curves can be explained through the influence of the various operating factors on the above variables. For example, the effect of fuel-air ratio on heat loss is due chiefly to a change in ΔT. The temperatures of the gases during expansion vary with fuel-air ratio in a manner quite similar to the variation in heat loss shown in Fig. 3. The reduction in total heat loss with increase in compression ratio (Fig. 4) is also due to the effect on ΔT, the average temperature during expansion being lower with the higher compression ratio. It is interesting to note that increasing the compression ratio *increased* the heat rejected to the head, although the heat loss to the barrel and exhaust port decreased. This is due to the fact that an increase in compression ratio in-

creases the temperatures at the beginning of expansion and decreases the temperatures near the end of expansion. The increase in heat loss with increasing spark advance (Fig. 5) is again explained through the influence on ΔT. Advancing the spark advances the time at which combustion occurs and this raises the average temperature of the cycle, although it has very little effect on the maximum temperature. The increase in heat loss with increasing r.p.m. (Fig. 6) is undoubtedly due chiefly to the increase in relative velocity between gases and cylinder walls. Variables which would effect the density factor include throttling and supercharging, but these were not covered in the present investigation.

In attempting to explain the distribution of heat loss to the three jacket spaces, it is necessary to take into account not only the temperature difference, velocity and density, but also the area exposed and the time during which such area is exposed. While it is quite impossible to evaluate all of these factors with accuracy, the estimate given in Table II is of interest in this connection.

The Design of a Stratosphere Rocket*

ALFRED AFRICANO, *American Rocket Society*

(Received April 21, 1936)

Summary

AFTER making several attempts during the years 1932, 1933, and 1934, to launch liquid-fuel rockets with only two partially successful flights, the Experimental Committee of the American Rocket Society decided that proving stand development of the rocket reaction motor was urgently needed and had to be undertaken before further progress could be made. Consequently, in the following year, 1935, four series of ground tests were conducted on a proving field provided by G. E. Pendray, president of the Society, at Crestwood, N. Y. The data obtained from the careful records made of the reaction, the fuel and liquid-oxygen feed pressures, the combustion chamber pressure, and the duration of the reaction for over 25 rocket motors was used in deriving three empirical rocket design formulas, which are presented in this paper. With these formulas as the basis for the rational design of a liquid fuel rocket, it is shown that the present development of the rocket motor is already sufficient to propel a meteorological rocket to an altitude of 7½ miles.

The American Rocket Society Motor Tests[1]

The apparatus used in the tests is shown in Fig. 1. An instrument panel containing five gages which represented the chamber, fuel, and liquid-oxygen pressures, the reaction, and the time in seconds, was photographed with a motion picture camera to obtain a continuous record of the relation of these quantities during each run. In addition, detailed records were kept of the kind and amount of fuel and liquid-oxygen used, the dimensions of the rocket motors, and all observed phenomena.

The procedure of the tests consisted of: (1) placing a definite amount of alcohol (or gasoline) in the fuel tank, then forcing in nitrogen gas to 300 lbs. per sq. in. pressure; (2) placing the corresponding amount of liquid-oxygen required for combustion in the other tank (allowing for loss due to evaporation), then closing all valves; (3) allowing the pressure of the gaseous oxygen above the liquid-oxygen to build up to 300 lbs. per sq. in. by heat absorption from the surrounding air; and (4) opening the quick-release valves which caused the liquids to flow into the combustion chamber, at the same time closing an ignition circuit.

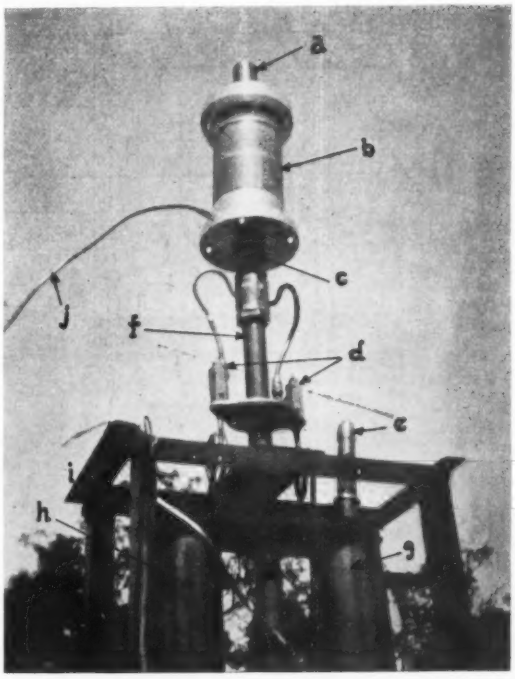


Fig. 1. Typical A.R.S. rocket motor in position for a test. (Motor and proving stand designed by John Shesta).
a. Nichrome nozzle.
b. Aluminum combustion chamber.
c. Fuel and oxygen inlets.
d. Quick-opening valves.
e. Safety valve.
f. Hydraulic piston (to convert reaction to gage reading).
g. Copper liquid-oxygen tank.
h. Copper liquid-fuel tank.
i. Angle-iron proving stand frame.
j. Pipe connection to chamber pressure gage.

Fig. 2. shows the typical graphs obtained from the photographic records. Since the jet reaction equals the mass flow per second times the jet velocity, an average value for the jet velocity can now be calculated. Using the average reaction from the graph, (57 lbs.) and the average input of the liquids, (.42 lbs. per sec.) the weight of 1½ pints of alcohol plus 1 quart of liquid-oxygen divided by 8½ seconds duration, the resulting jet velocity by this method is 4350

*Abstract of a thesis of the same title, which will be printed and made available shortly.

[1] Detailed technical reports of these tests can be found in Nos. 31 to 34 of *Astronautics*, Journal of the American Rocket Society.

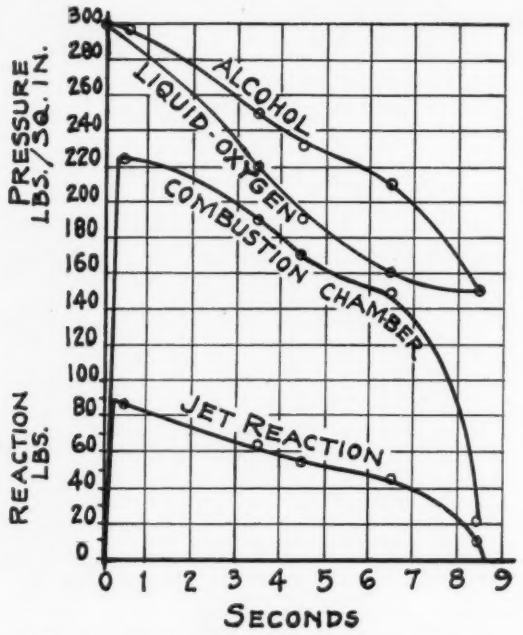


FIG 2. Typical graph of a rocket motor test run.

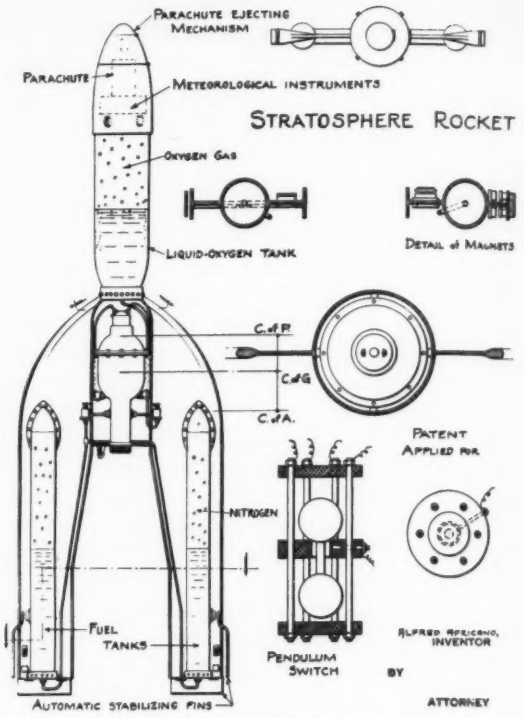


FIG. 3. Stratosphere rocket.

ft. per sec. The maximum reaction is 90 lbs. for this motor with a ½ inch nozzle throat diameter.

The kinetic energy output of the jet is next calculated, and compared to the heat energy input of the fuel. Calling this ratio the overall thermal efficiency[2] of the rocket motor (this includes the combustion chamber and nozzle losses), the numerical result for this case is 8½%. It should be noted that this efficiency does not tell how much of the jet energy is available for propulsion of the rocket proper. The availability is purely a function of the ratio of the rocket velocity to the jet velocity (therefore called the "velocity-ratio efficiency" by the writer).

Comparative Performance of Gunpowder and Alcohol as a Rocket Fuel

To obtain experimental proof for the much discussed theoretical advantage of liquid-fuels over gunpowder tests were made with various sizes of pyrotechnic rockets. The largest size available was that designated commercially as the "6 lb. rocket," containing .75 lb. of gunpowder, which gave an average reaction of 27 lbs. during 1.12 seconds, a resulting jet velocity of 1300 ft. per sec., and a thermal efficiency of 2.6%. Since the alcohol-liquid-oxygen mixture gave a thermal efficiency of 8½%, and further, contains three times as much heat energy per lb., the practical advantage of the alcohol was seen to be even greater than that theoretically indicated. The alcohol actually produces about 10 times as much kinetic energy output per lb. of the explosive mixture as the gunpowder.

[2]Since nearly all of the kinetic energy of the jet gases could be converted into mechanical kinetic energy if used in a gas turbine instead of in a rocket, it seems justifiable to call this ratio the "thermal efficiency."

Derivation of Empirical Rocket Design Formulas

By plotting all the data showing the relation of the jet reaction to the combustion chamber pressure for the motors having a ½ inch nozzle, the following tentative formula was obtained:

$$R = .31P_c = 1.55\,A\,P_c \qquad (1)$$

where R is the jet reaction in lbs., P_c is the chamber pressure, gage, and A is the area of the nozzle, sq. in.

Similarly, the relation of the jet flow to the chamber pressure was shown to be:

$$w = .0027\,P_c = .0135\,A\,P_c \qquad (2)$$

where w is the jet flow in lbs. per second.

A third equation expressed the relation between the feed-tank pressures and the chamber pressure for the particular apparatus used,

$$P_c = .75\,P_f \qquad (3)$$

where P_f is the tank feed pressure, lbs. per sq. in. gage.

Combining Eqs. 1 and 2 gives a convenient relation between the jet reaction and the jet flow:

$$R = 115\,w \qquad (4)$$

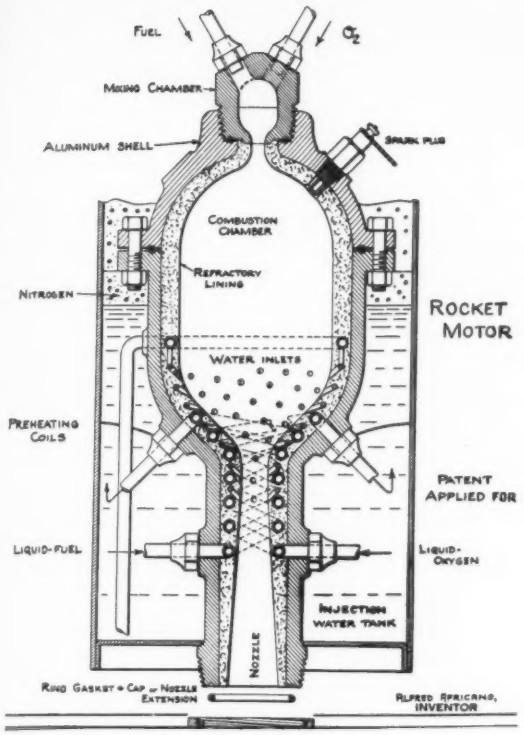


FIG. 4. Rocket motor.

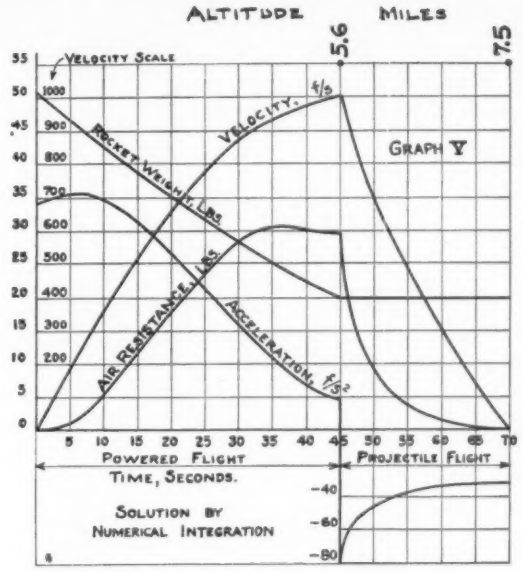


FIG. 5. Calculated values of acceleration, velocity, air resistance, and altitude.

Upon examination, these formulas are seen to be based on an average jet velocity of 3700 ft. per sec., and an average thermal efficiency of about 7%. It is probable that the jet velocity was limited since the incomplete expansion in the nozzle made the latter little better than a simple orifice, where the maximum exit velocity is that of sound at the temperature of the jet gases (*c.* 3000° F.). With a properly designed nozzle it should be possible to get much higher velocities and efficiencies. Since the purpose of this paper is to show what can actually be expected of a rocket, however, only the experimental values will be used in the following calculations.

RATIONAL DESIGN OF A LIQUID-FUEL ROCKET

The general layout of the tanks, rocket motor, and necessary equipment is shown in Fig. 3. The method of fuel injection is the same as that used in the ground tests, i.e., allowing the gas under high pressure above the liquids to expand and force them into the motor when the valves are opened. The space allowed for the gas is made the same as that required for the liquid volume so that the adiabatic expansion will be from 450 lbs. per sq. in. initial to 225 lbs. per sq. in. final feed pressure. From Eq. 3 the corresponding combustion chamber pressure is found to vary from 338 lbs. per sq. in. to 169 lbs. per sq. in. From Eq. 1, the reaction is found to vary from 104 lbs. to 52 lbs. for the ½ inch nozzle to be used. Eq. 2 then shows that the weight of flow will vary from .91 to .46 lbs. per second, so that the total weight of liquids required for 45 seconds of reaction will be 31 lbs. Of this, 10 lbs. will be alcohol, and 21 lbs. must be liquid-oxygen for complete combustion. From their specific gravities, .79 and 1.14 respectively, the required volume of their tanks is next computed. The general dimensions found in this way are: for the liquid-oxygen tank, 5 in. inside diameter, and 4 ft. long; for the fuel tanks, 3½ in. inside dia., and 3 ft. long. The required wall thickness is calculated from the usual formulas for internal pressure. With an additional 2 ft. for the rocket motor and parachute compartment the overall length of this rocket will be 9 ft. Details of the rocket motor are shown in Fig. 4.

CALCULATION OF THE PROBABLE ALTITUDE

The least dead weight of the rocket that will provide a reasonable factor of safety for the 17 ST aluminum used is 20 lbs., so that the total weight will vary from 51 lbs. at the take-off to 20 lbs. when the fuels are completely consumed, 45 seconds later, and will remain constant thereafter. The first or accelerated part of the flight can be compared to the problem in interior ballistics of the action of a projectile within the gun. The second or decelerating part of the rocket trajectory is analysed exactly as is the projectile in flight in exterior ballistics. The beauty of the rocket principle and the startling possibilities of the liquid-fuel rocket as a new war weapon are evident when it is realized that its development may soon make the slow cumbersome movement of heavy ordnance quite obsolete. One advantage of the rocket, a steadily increasing velocity at the higher altitudes where the

air resistance is less of a retarding influence, is already realizable, as the following calculations show.

The several variables are handled by taking short intervals of one second, assuming constant conditions during the interval, and applying the method of numerical integration as used in exterior ballistics. The calculations were arranged in tabular form for convenience, and the results plotted in Fig. 5. The principal formula used was the familiar Newton's second law, to obtain the acceleration due to the net upward force acting on the rocket, after subtracting the proper values of the total weight and air resistance from the corresponding jet reaction. During deceleration, or the projectile flight, the total force acting downward on the rocket is the sum of its weight and the air resistance.

The air resistance formulas used were derived from the Mayevski series for retardation of projectiles (Hermann's Exterior Ballistics, p. 21, 1930). The exponent was varied from 2 in the first velocity zone, to 3 in the second zone, and to 5 in the third zone—the coefficients being varied to correspond. The maximum velocity attained in a vacuum would be 2000 ft. per sec. (1360 m.p.h.). Air resistance cuts this down to 1000 ft. per sec. (680 m.p.h.). The maximum altitude in the vacuum would be 20 miles; in air, the result is 7½ miles, of which 5.6 miles is powered flight and 1.9 miles is the projectile flight.

Efficiency of Flight

(a) The Velocity-Ratio Efficiency[3]. (In space; no air resistance or gravity loss).

As an approximation to this condition consider a perfectly streamlined rocket propelled sled on frictionless ice. If the sled is prevented from moving, the kinetic energy of the jet is entirely wasted; if the sled travels forward at the same speed that the gases are ejected rearward, the gases will have no residual or absolute motion left and therefore no wasted kinetic energy so the jet energy is completely utilized in propulsion. By considering the relation between the wasted energy and the constant jet energy available per second an equation can be derived for the instantaneous efficiency at any velocity as follows:

$$E = \frac{\text{Input - Output}}{\text{Input}} = \frac{(mc^2/2) - m(c - v)^2/2}{mc^2/2} = 2r - r^2 \qquad (6)$$

where E is the instantaneous efficiency, m is the mass flow of the jet per second, c is the constant jet velocity relative to the rocket, v is the varying rocket velocity, and $r = v/c$, the velocity-ratio. Since this efficiency is seen from Eq. 6 to be purely a function of the velocity-ratio, it is logical to designate it the velocity-ratio efficiency to make that fact apparent. Note that where $r > 2$, this efficiency becomes negative. This is possible because the rocket is losing a mass m (fuel and oxygen) having a greater amount of residual kinetic energy than can be imparted to the remaining mass by the continued acceleration. The velocity of the rocket keeps increasing, but the total kinetic energy must naturally decrease since the loss per second exceeds the gain.

For the case of constant acceleration from zero velocity the average efficiency over the interval is the mean ordinate of the graph of Eq. 6. By integrating the area under the curve and dividing by the abscissa r this is:

$$E_a = r - (r^2/3) \qquad (7)$$

This average reaches a maximum of 75% when $r = 1.5$. If the reaction can be reduced when $r = 1$ (100% instantaneous efficiency) to that required only for overcoming air resistance and for lift the average velocity-ratio efficiency over a long period could be made to approach 100%. For the rocket designed here, the maximum velocity-ratio would be 1000/3700, or .27, and the corresponding efficiency from Eq. 6 would be 47%. The average efficiency cannot be calculated from Eq. 7 because the acceleration is not constant for this case. However, by plotting several values of the instantaneous efficiency against time, and averaging graphically, the average velocity-ratio efficiency for the 45 seconds of powered flight is found to be 33%.

(b) Vertical Flight Efficiency in Air.

If the work done in lifting the final weight of the rocket to its maximum height is divided by the total jet energy delivered during the 45 seconds of combustion, this ratio will indicate the overall efficiency of vertical lift. For this case it is 11%. Combining the two principal efficiencies of this rocket, that of the power plant, or combustion chamber and nozzle, 7%, and that of vertical flight, 11%, the final overall efficiency is about .8 of 1%.

Conclusion

The several losses which occur in a rocket's flight may be summarized as follows: loss in combustion chamber because of dissociation at the high temperatures, loss in nozzle because of incomplete expansion and the heat rejected, loss because of the velocity-ratio, loss with low acceleration (sustentation requires an acceleration of 32 ft. per second, simply to overcome that of gravity downward before any useful lifting is done, and naturally the higher the acceleration above this the smaller the proportion of the fixed loss), loss due to the ratio of fuel weight to rocket dead weight, and the loss due to air-resistance.

[3]For a more detailed discussion of this efficiency see the author's article on *The Velocity-Ratio Efficiency*, Astronautics, October 1935.

An Air Spoiler

A. A. MERRILL, *Pasadena Junior College*

(Received May 25, 1936)

I am sending a short article by A. A. Merrill, which seems to me to be of some general interest. As you may know, Merrill is one of the very old-timers in aeronautical research, having been one of the organizers of the Boston Aeronautical Society in 1895. This Society published the Aeronautical Annuals edited by James Means. He was, for some years, connected with the California Institute and had charge of a small wind tunnel here which was built during the War. For the last few years he has been operating a small wind tunnel at the Pasadena Junior College, doing instruction and commercial testing as well as his own research.

CLARK B. MILLIKAN

THE problem of landing an airplane should be divided into two parts, namely, before and after ground contact. Before ground contact the desirable thing is to increase C_L as much as possible without increasing the angle of attack, and to lower the L/D ratio. Both of these things are well cared for in current practise by means of the trailing edge flap and the lowered retractable landing gear.

Immediately after ground contact it would be desirable to decrease the C_L as much as possible and increase the wing drag. The air-spoiler described here does this. Fig. 1 shows a wing with this spoiler. There is an airtight passage from bottom to top of the wing, which in normal flying is closed by airtight panels. When coming in to a landing and after the landing gear is down, the pilot can move a lever which frees the panels but does not open them. The panels are opened only when ground contact compresses the landing gear. With the panels closed there is, of course, a pressure difference between the bottom and top of the wing and when the panels open this pressure difference immediately turns into velocity and air rushes up and out through the top slot as jets shown by the little arrows. Aerodynamically this is something like the Handley-Page slotted wing but for the reverse effect. Because of their position and direction, the jets spoil the top air flow immediately.

Fig. 2 shows the performance as tested in the Pasadena Junior College wind tunnel with slots closed and open. The model used was a high wing monoplane with a short stub wing put on simply to house the retractable landing gear. The dimensions of the flap are: length 45.2% of the wing span; width 27.2% of the wing chord. The slot dimensions are: top width 0.85 of 1% of wing chord; bottom width 7.5% of wing chord. The length of the slot is 72.1% of the wing span and the slot is placed 19.5% of the wing chord back of the leading edge.

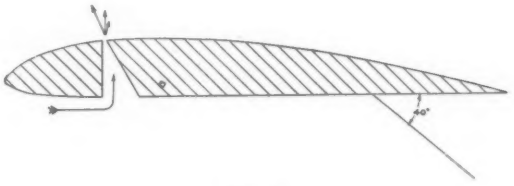


FIG. 1.

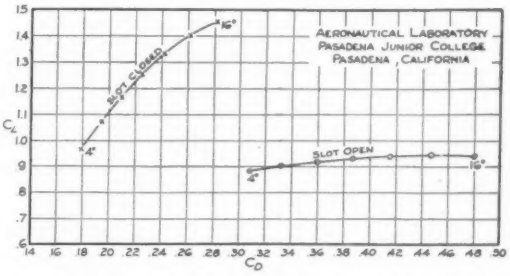


FIG. 2. Polar for wing with slot closed and slot open.

Polar No. 1 shows the performance with landing gear and flap down and the slot closed. Polar No. 2 shows the performance with the slot open and no other change. The lift will be reduced and the drag increased very suddenly when the slot opens. A sudden drop in lift and rise in drag at the moment of ground contact will make the landing problem easier for the pilot to handle.

The wind speed in these tests was 57.1 ft./sec. and the Reynold's number was 142,500.

Eleventh Annual Aircraft Engineering Research Conference

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS, *Langley Field, Virginia*

(May 20, 1936)

SECTION A of the Eleventh Annual Aircraft Engineering Research Conference of the National Advisory Committee for Aeronautics was held on Wednesday, May 20, 1936, at the Committee's laboratory, the Langley Memorial Aeronautical Laboratory, at Langley Field, Virginia. For the first time the conference was held in two sections. Section A included in general the representatives of aircraft manufacturers and operators and Government officials. Section B, which was held on May 22, included the personnel of governmental agencies using aircraft, representatives of engineering societies, and members of the faculties of professional schools.

The purposes of this annual conference were twofold: First, to afford to the representatives of the industry an opportunity to receive first-hand reports of progress in aeronautical research at the Committee's laboratory and to witness demonstrations of the special facilities and methods used; and second, to enable the Committee to obtain the comments and suggestions of the industry as to the research problems which are deemed of particular importance at the present time and which the Committee is especially equipped to study.

The National Advisory Committee for Aeronautics was represented at Section A of the conference by its officers and members and also by its Committees on Aerodynamics and Power Plants for Aircraft and by members of its laboratory staff.

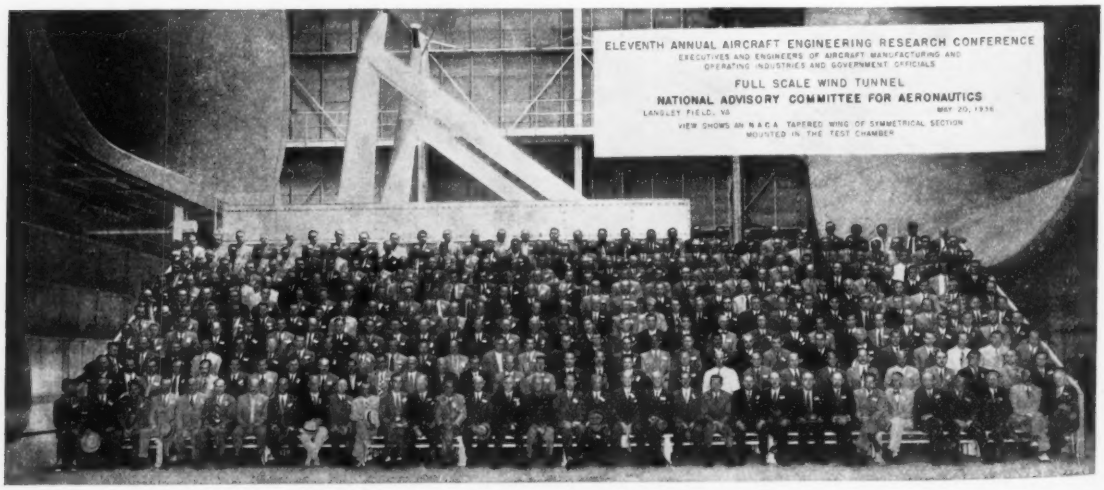
The opening session was held at 8:45 a. m. in the Post Theater at Langley Field.

The Chairman of the conference, Dr. Joseph S. Ames, Chairman of the National Advisory Committee for Aeronautics, was prevented by illness from being present, and in his absence William P. MacCracken, Jr., a member of the Committee, presided.

Brief addresses of welcome were made by the Presiding Officer on behalf of the National Advisory Committee for Aeronautics; by Major-General Frank M. Andrews, Air Corps, Commanding General of the General Headquarters Air Force; and by Brigadier-General Henry C. Pratt, Air Corps, Commanding Officer of Langley Field, also Commander of the Second Wing of the General Headquarters Air Force, and a former member of the National Advisory Committee for Aeronautics.

Henry J. E. Reid, Engineer-in-Charge of the Langley Memorial Aeronautical Laboratory, called upon certain members of the laboratory staff in turn to present and explain, with the aid of charts, some of the important results of investigations conducted by the Committee during the past year.

Elton W. Miller, Chief of the Aerodynamics Division of the laboratory outlined in general the investigations being conducted by the Committee in the improvement of aerodynamic efficiency, including in particular the best methods of the application of airfoil data to wing design, wing-fuselage interference


ELEVENTH ANNUAL AIRCRAFT ENGINEERING RESEARCH CONFERENCE
EXECUTIVES AND ENGINEERS OF AIRCRAFT MANUFACTURING AND OPERATING INDUSTRIES AND GOVERNMENT OFFICIALS
FULL SCALE WIND TUNNEL
NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS
LANGLEY FIELD, VA
MAY 20, 1936
VIEW SHOWS AN N.A.C.A. TAPERED WING OF SYMMETRICAL SECTION MOUNTED IN THE TEST CHAMBER

with elliptical and triangular fuselages, the optimum fuselage form, the effect of rivet heads on aerodynamic drag, and the effect of idling or stopped propellers on airplane lift.

Fred E. Weick, Assistant Chief of the Aerodynamics Division, discussed the Committee's study of stability and control of airplanes and exhibited charts of some of the results obtained.

Starr Truscott, Chief of the Hydrodynamics Division, explained the investigations in the N.A.C.A. tank during the past year, including a study of the effect of rivet heads on take-off, the optimum shape of wing-tip float for large seaplanes, a comparison of the take-off performance of various European and American seaplane hulls, and a comparison of single-hull and double-hull flying boats.

Dr. Theodore Theodorsen, Chief of the Physical Research Division, discussed the investigation of the cowling and cooling of air-cooled engines, particularly the analysis of the many factors entering into the design of a successful N.A.C.A. cowling.

Carlton Kemper, Chief of the Power Plants Division, described some of the principal results of investigations of aircraft engines, including a comparison of the performance of carburetor-type and Diesel-type engines, a comparison of air cooling in flight and on a single-cylinder test engine, the effect of fin spacing on the cooling characteristics of an engine cylinder, and the variation in engine cylinder temperatures with variation in temperature of the cooling air.

The members of the conference then proceeded in groups on a tour of inspection of the laboratory.

Propeller-Research Tunnel. At the propeller-research tunnel charts were shown of results obtained in the investigation of the effect on control and performance of a two-engine airplane after failure of one engine. The large model equipped with operating propellers, which was used in the investigation, was shown in test position in the tunnel. Results were also presented of the analysis of problems of propeller design, showing the efficiency likely to be obtained under various conditions.

Eight-Foot High Speed Wind Tunnel. At the new eight-foot high-speed wind tunnel, which was opened for inspection for the first time, the principal design features of the tunnel were briefly described. It was stated that the tunnel proper had a working section eight feet in diameter and a range of air speeds from 85 miles per hour to 500 miles per hour and that the tunnel was operated by an 8000-horsepower electric motor driving an 18-blade propeller 16 feet in diameter. Charts were shown of results obtained in the Committee's smaller high-speed wind tunnel of the pressures on propeller blade sections and the loss in energy corresponding to increased drag at very high speeds.

Free-Spinning Wind Tunnel. At the free-spinning wind tunnel charts were shown of the influence upon spins of the arrangement of tail surfaces; a comparison between spinning characteristics as determined by the spinning balance in the N.A.C.A. vertical wind tunnel as observed in the free-spinning wind tunnel, and as determined in actual flight; and a method of the rapid estimation of lateral-stability characteristics of airplanes. Demonstrations were made in the tunnel of the spinning characteristics of a small pusher-type double-tail airplane with three-wheel landing gear and of a low-wing monoplane of modern type with and without the addition of a small area at various parts of the tail.

N.A.C.A. Tank. In the N.A.C.A. tank a model of a hull equipped with a hydrofoil was towed through the water and on an illuminated chart a curve was developed showing the improved drag characteristics of the model with the hydrofoil as compared with the same model without the hydrofoil, resulting in decreased time and distance of take-off. Charts were exhibited and shown of the effect on take-off of rivet heads on the bottoms of flying-boat hulls, and the effect of ventilating the step to improve take-off characteristics.

N.A.C.A. Hangar. At the N.A.C.A. hangar charts were shown of results obtained in the study of high-lift and lateral-control devices on full-scale airplanes, the investigation of the column strength of stiffeners for stressed-skin construction, and the measurement of accelerations on transport airplanes in gusty air. A demonstration was given of the effectiveness of a swiveling or castering wheel when placed below the airplane forward of the center of gravity in the prevention of ground looping.

Engine Research Laboratory. At the aircraft engine research laboratory charts were shown of results obtained in the investigation of the high-speed aircraft Diesel engine, and a single-cylinder engine of this type, having a displacer form of combustion chamber, was shown in operation. A special glass-cylinder engine for the study of the mixture of injected fuel and air in a fuel-injection engine was exhibited. In this cylinder smoke is used to make the air movement in the cylinder visible during the suction and compression stroke and the air movement and fuel spray distribution are photographed by high-speed motion pictures.

Variable-Density Wind Tunnel. At the variable-density wind tunnel charts were shown indicating the development of a method for the rational selection of wing sections for airplane design according to the requirements of the airplane. A demonstration was given in the smoke-flow tunnel of laminar and turbulent boundary-layer flow and of the effect of rivet heads on the turbulence of the flow.

Atmospheric Wind Tunnel. A demonstration was given in the atmospheric wind tunnel of a tapered wing designed so that the center section of the wing stalled first instead of the tip section. In this demonstration the stalling characteristics of this wing were shown, as well as the stalling characteristics of an ordinary tapered wing which stalled first at the tip section. White silk tufts fastened at various places over the wing surface were used to indicate the character of the air flow, and the model as tested with both wings was mounted so as to be free to rotate and free to pitch about its center of gravity. It was shown that when the tips stalled first the model had a strong tendency to autorotation and spinning, whereas with the wing without tip stall this tendency was very greatly reduced.

Physical Research. Charts were shown presenting in greater detail the Committee's investigation of the factors involved in the design of a cowling and the new N.A.C.A. nose-type cowling was shown mounted on the front part of a fuselage.

Full-Scale Wind Tunnel. Charts were exhibited of the results of the Committee's investigation of the effect of aspect ratio for airship fins and of the forces on an airship in ground handling. Information was presented as to the effect of engine nacelles on the stall of highly tapered wings, on the effect of propeller slipstream upon the span loading of wings, and on the effect of locked and windmilling propellers with nacelles located in the leading edge upon the maximum lift coefficient.

H. J. E. Reid announced that, as shown on the programs, seven simultaneous conferences would be held for the discussion of seven different subjects.

Conference on Flying and Handling Characteristics

Edward P. Warner, a member of the National Advisory Committee for Aeronautics and Chairman of the Committee on Aerodynamics, presided at this conference.

After a brief introductory statement the conference proceeded to the consideration of the subject in accordance with the following outline:

(1) Lateral control:
New criterions for comparison.
Differential linkages.
Special wings with unstalled tips.

(2) Control forces that can be exerted by pilots.

(3) Lateral stability.

(4) Longitudinal stability—Measured stability compared with pilot's feel of stiffness.

(5) Taxying stability.

(6) Take-off and landing with high-lift devices;
Wind-tunnel data.
Flight results.

(7) Quantitative measurement of flying and handling qualities.

Conference on Aerodynamic Efficiency and Interference

Dr. H. L. Dryden, of the National Bureau of Standards, a member of the Committee on Aerodynamics, presided at this conference.

Charts were presented and explained by members of the Committee's staff and the data covered by the charts were discussed. Questions were asked and suggestions for future work were submitted by the guests.

The discussion of the subject in general followed the outline given below:

(1) Air-flow fundamentals—Scale effect.

Scale effect for the pressure distribution on an airfoil section.

The nature of the transition phenomenon and its relation to the drag scale effect.

Airfoil scale effect.

(2) Tapered Wings—Application of section data to design of tapered wings.

(3) Compressibility effects—Propellers.

Application of compressibility investigations to propellers.

Fundamental investigation.

(4) Improvement of airfoil sections and wing-fuselage combinations (interference).
Airfoil section development.
Wing-fuselage interference.

Conference on Aerodynamic Consideration of Cowling and Cooling

Dr. George W. Lewis, Director of Aeronautical Research of the National Advisory Committee for Aeronautics, presided at this conference.

The information presented at this conference included the following subjects:

(1) Cowling nose design—Frontal opening.
(2) Skirt design—Regulation of air flow for cooling.
(3) Cooling as affected by cowling.
(4) Effect of propeller on cowling design.
(5) Effect of baffling of engine—Conductivity.
(6) Effect and use of spinners.
(7) Effect of inner cowl—Design of exit opening.
(8) Effect of size of nacelle or afterbody.
(9) "Pump efficiency".
(10) Factors affecting cooling on the ground.
(11) Skirt flaps, large hub sections, fans, and blowers.
(12) Differences in efficiencies of propellers.
(13) New N.A.C.A. nose-type cowling.

Conference on Power Plant Consideration of Cowling and Cooling

Henry J. E. Reid, Engineer-in-Charge of the Langley Memorial Aeronautical Laboratory, presided.

The discussion at the conference included the following subjects:

(1) Correction factor for variation in cooling air temperature.

(2) Investigation of the cooling of the Wasp S1H1-G engine.

(3) Aerodynamics of investigation of N.A.C.A. cowling.

(4) Investigation of cowling and cooling of in-line air-cooled engine.

(5) Finned-cylinder investigation.

(6) Correlation of cooling obtained in flight and in tests with single-cylinder engine.

(7) Blower cooling.

Conference on Aircraft Engine Research

Dr. H. C. Dickinson, of the National Bureau of Standards, a member of the Committee on Power Plants for Aircraft, presided at this conference.

Charts were exhibited and explained by members of the Committee's staff giving results obtained in the investigation of aircraft engines, particularly of the compression-ignition type. The data presented included information as to the new N.A.C.A. fuel flowmeter developed by the laboratory in connection with its investigation of the reduction of fuel consumption of aircraft engines. The subjects discussed at this conference were as follows:

(1) Reduction in fuel consumption—N.A.C.A. fuel flowmeter.

(2) Fuel-injection spark-ignition engines.

(3) Research on performance obtained with high octane number fuels.

(4) Distribution and exhaust gas analysis.

(5) Compression-ignition engine research.

(6) Investigation of ignition and combustion of Diesel fuels.

(7) Rate of fuel injection.

Conference on Seaplanes

Starr Truscott, Chief of the Hydrodynamics Division of the Committee's laboratory, presided at this conference.

Charts were exhibited and explained by members of the staff of the N.A.C.A. Tank on the following subjects:

(1) Effect of rivets on water drag of seaplane hulls.

(2) SVA type floats and hydrofoils.

(3) Ventilation of step of flying-boat hull.

(4) Wing-tip floats—Hydrodynamic characteristics.

(5) Wing-tip floats—Aerodynamic characteristics.

(6) Comparison of stub wings and floats.

(7) Comparison of single-hull and double-hull designs.

(8) Comparison of characteristics of improved designs of large seaplanes, both European and American.

There was general discussion of the charts and of the problems of seaplane design. In addition to the subjects covered by the charts the following problems were discussed:

(a) Controllability and maneuverability of seaplanes on the water.

(b) Form of presentation of results from N.A.C.A. Tank.

(c) Minimum time and distance of seaplane take-off—Development of special instruments.

Conference on the Autogiro

John W. Crowley, Jr., head of the Flight Research Section of the Committee's laboratory, presided.

Charts of results obtained by the Committee in its investigation of autogiros were presented and discussed. The following subjects were considered:

(1) Stability of the autogiro rotor.

(2) Rotor vibration.

(3) Rotor efficiency.

Institute Notes

Corporate Members

The Institute welcomes as Corporate Members the following companies:

The B. G. Corporation
Curtiss-Wright Corporation
Douglas Aircraft Company
Eclipse Aviation Corporation
Edo Aircraft Corporation
Ethyl Gasoline Corporation
Fairchild Aviation Corporation
The Glenn L. Martin Company
The Goodyear Tire & Rubber Company
Kollsman Instrument Company
The Northrop Corporation
Socony-Vacuum Oil Company
Sperry Gyroscope Company
Stanavo Specification Board
Summerill Tubing Company
The Texas Company
United Aircraft Manufacturing Corporation

These companies joined as Corporate Members before any general announcement of the new grade was sent to other companies by mail.

The requirements and dues of Corporate Members for 1936 are as follows:

Corporate Members shall be manufacturers or operators of aircraft or producers of equipment or supplies used in aeronautics who contribute annually to the Institute of the Aeronautical Sciences.

The annual dues for manufacturers of airplanes, airships, or aircraft engines shall be $200, or 1/20th of one percent of their gross annual business, whichever is larger, but shall in no case exceed $2,500 for any one company. If the income of the Institute from this group shall exceed $18,000, the dues received in excess of that amount will be rebated on a pro rata basis.

The annual dues from all other companies shall be any amount they feel is proportionate to their gross annual business in the aeronautical field, but in no case to be less than $200.

For each $100 contributed, Corporate Members will be entitled to five annual subscriptions to the Journal of the Aeronautical Sciences, to be mailed to other than their employees.

It is hoped that eventually the work of the Institute will, like that of other scientific societies, warrant an endowment—the income from which will meet its expanding needs. But until it has earned a reputation for rendering a service to the scientific progress of aeronautics, the Council desires only to secure an income which permits it to bring together the results of research now being conducted in aerodynamics as well as in the allied sciences. The Council believes that this country should have an effective engineering and scientific aeronautical organization. It believes that those companies engaged in aeronautical work will wish to help maintain and enlarge the work of the Institute.

Advertising in the Journal, which has been paying the cost of publication, has been discontinued, as the Council believed that companies would prefer to make their contributions directly instead of indirectly through advertising, which gave the Institute only a portion of the appropriation—due to expenses of commissions, printing, etc. The Journal is using the pages on which advertising formerly appeared for the review of current aeronautical literature, thus rendering a greater service to those who are too busy to do comprehensive reading of the aeronautical publications.

Meetings

So that members may make plans well in advance of meetings to be held by the Institute, preliminary notices will appear in the Journal even before the definite dates are set.

On December 4th, a dinner in honor of Dr. George W. Lewis, Director of Aeronautical Research, National Advisory Committee for Aeronautics, will be held at the Hotel Biltmore, New York, at which dinner the Institute will present to Dr. Lewis the Daniel Guggenheim Medal *"for outstanding success in the direction of aeronautical research, and for the development of original equipment and methods."*

This is the first occasion at which the Institute has been privileged to present this distinguished award. Guests will be invited from foreign countries and the United States to felicitate the recipient of the medal and appraise the outstanding contributions to aeronautics made by the National Advisory Committee under his direction.

During the day the American Society of Mechanical Engineers, in cooperation with the Institute, will hold a meeting at which the progress of aerodynamics during 1936 will be discussed by speakers who are authorities in their specialized aeronautical fields. Several foreign countries have been invited to send films to be shown at the meeting which will give some idea of the great advances made during recent years in the construction of wind tunnels and laboratories abroad.

During the last week in December the Institute will hold a meeting at Atlantic City in connection with the American Association for the Advancement of Sciences. It is planned to have a small aeronautical exhibit at the Science Show which is a part of these meetings.

As is customary, the Annual Meeting and Annual Dinner of the Institute will be held during the last week in January, 1937. As this will occur during the period of the Aeronautical Exposition to be held in New York, a large attendance is expected.

Awards

The Sylvanus Albert Reed Award *"for a notable contribution to the aeronautical sciences resulting from experimental or theoretical investigations, the beneficial influence of which on the development of practical aeronautics is apparent,"* will be considered by the Fellows of the Institute during the Fall. Members wishing to present the names of candidates for this award may send to the Secretary of the Institute a statement giving a complete description of the work done for whch they believe the award would be justified.

The Lawrence B. Sperry Award for an outstanding achievement in aeronautics by a young man will also be considered by the Committee of the Award. While the specific rules for the award are now being prepared, it may be stated that any member knowing of such an achievement by a young man may send his name with a general statement of his work to the Secretary of the Institute, who will submit it to the committee.

Student Branches

Carnegie Institute of Technology. A final meeting of this branch for this year was held May 11th. Robert D. Gilson presided. Several of the Senior students, who had taken trips through the East earlier in the Spring in order to make contacts and secure work after graduation, read reports on their trips. Joseph R. Schaffer reported

on the manufacturing methods used by the Wright Aeronautical Corporation, and Robert W. Halli's report was a review of all the airplane manufacturing companies.

The election of officers for the following year was held and W. Wheeler was elected as Chairman, W. J. Closs as Vice-Chairman, and D. M. Pote as Secretary-Treasurer.

University of Michigan. A final meeting of this branch was held on Tuesday, May 19th. Chairman McCance read a letter from Professor J. A. Bursley, Dean of Students of the University of Michigan, granting official recognition to this Student Branch of the Institute of Aeronautical Sciences. B. L. Springer, Honorary Chairman of this branch, gave a talk concerning the different groups of membership, the fees, the status of the student after graduation, and the plans for next year.

The election of officers for next year was held and Willis M. Hawkins was elected as Chairman, John A. Margwarth as Secretary, and Robert L. Camping as Treasurer. John C. Duffendack was elected as representative to the Engineering Council, the student governing body.

Louisiana State University. A final meeting of this branch was held recently at which officers for the following year were elected. F. A. Ford was elected as President, R. Frederick as Vice-President, and R. L. Montoney as Secretary-Treasurer.

Personnel Opportunities

The Personnel Bureau serves organizations seeking to employ aeronautical specialists as well as individual members. The Bureau has been the means of arranging several very successful connections for members.

Any member or organization may have requirements listed without charge.

Available

Design engineer wishes to make new connection. Fifteen years' military and commercial aircraft experience in England and America. Would prefer technical post where knowledge of skin-stressed metal structures and aerodynamics could be used to advantage. Thoroughly familiar with Army and D. C. requirements. Graduate aeronautical engineer, London University, 1922. Write Box 46, Institute of the Aeronautical Sciences.

Recently graduated Student Members of the Institute wishing to secure some connection in the industry have forwarded to the Institute complete biographies of themselves and records of their school work. It would be appreciated if members or organizations offering employment to this type of personnel would write Box 47, Institute of the Aeronautical Sciences, stating their requirements.

Book Reviews

Engine Bearing Loading, by WILLIAM SAMUELS; Edwards Brothers, Ann Arbor, Michigan, 1936; 112 pages, ill., $3.00.

Aircraft engine designers will find of interest the material presented by Mr. Samuels in his latest book, in which he gives a complete discussion of the loading problem of engine crankshaft bearings and subsequently introduces a new method of determining and combining the various forces. A review of current methods is contained in the introduction.

In discussing this complex problem, the author develops a terse mathematical and graphical procedure of superior accuracy and reliability that shortens the time of a thorough bearing analysis to a small fraction of that required by prevailing systems. A single calculation is sufficient to determine the loads and PV values of a selected bearing for a continuous curve of a speed range from zero to 5,000 r.p.m. It also affords a real insight into the relative importance of gas and dynamic forces.

The Samuels method is confined to straight line and V engines of the carburetor type, applicable to either automotive or aircraft power plants. In the aircraft field, most liquid cooled engines of high power are of V design and require a thorough bearing analysis, in which case this new system should be an invaluable aid in arriving at a quick solution.

Providing that the cylinder diagram difference between carburetor and Diesel engines is properly considered, the system also can be applied without difficulty to four cycle Diesel engines of the straight line and V design, since the important "crossing point" of the two leading curves is practically identical for all four cycle engines. As to radial engines and those of unorthodox type, it should open a new field of investigation and thereby offers a basis of approach to their problems to obtain the same simple results.

Among the other engine subjects treated in the book are:

The importance of the PV value with regard to bearing temperatures, the balancing and counterbalancing of crankshafts, the effect of cheek obliquity on bearing pressures and the theoretical basis of tilt couple calculation, and the hydrodynamic theory of lubrication, including a critical survey of the significance of the ZN/P factor.

The technical analysis is supplemented by guide calculations and a separate atlas of illustrations.

J. R. CUSTER.

Annuaire de L'APNA; 6, RUE GALILÉE, Paris, France, 1936; 209 pages.

This Year Book of the Association des Professionnels Navigants de L'Aviation is an excellent book of reference for information concerning professional air pilots of France. The society is headed by Sadi LeCointe and its roster contains the names of many pilots who have made famous flights. The book is of particular value to those who wish to acquaint themselves with the requirements for a "Brevet" or license for any special aeronautical service.

The description of the "Maison des Ailes" which was founded by Suzanne Deutsch de la Meurthe in 1934 offers an idea which should be considered by some generous American as a possible benefaction to aeronautics in this country. This beautiful chateau which is located near Fontainbleu is maintained for rest and convalence for civil and military aviation personnel who are sick, have met with an air accident, or otherwise are in need of a place where they may recuperate. Pilots, observers, nagivators, engineers and mechanics are admitted for a reasonable time at a low charge. The Maison is surrounded by a beautiful park which permits the enjoyment of many sports. Such an establishment is needed in the United States.

LESTER D. GARDNER

Aerodynamic Theory, Vol. VI., W. F. DURAND, Editor-in-Chief; Julius Springer, Berlin, 1936; 286 pages, 127 figures and 2 plates.

The sixth and last volume of monographs by international authorities on the general subject of aerodynamic theory, published under a grant from the Guggenheim Fund for the Promotion of Aeronautics, tends to tie together the various treatments of aerodynamic theory in preceding volumes. There are five independent sections, viz., the Airplane as a Whole (31 pp.), the Aerodynamics of Airships (17 pp.), the Performance of Airships (85 pp), the Hydrodynamics of Floats (89 pp.), and the Aerodynamics of Cooling (58 pp.), together with a good index.

The section on the Airplane was originally intended to be the work of Professor Panetti of Turin whose "other engagements have not permitted him the time to prepare the manuscript". However, the Editor-in-Chief has supplied an illuminating survey of the general interference problem which sums up the detailed treatments by previous writers and gives a physical picture of what is admittedly a highly complex and not fully understood phenomenon. The airplane designer must obtain a satisfactory performance for his design by a happy interrelationship between the aerodynamics of the lifting system, the non-lifting system, the propulsive system and the control system.

Each of these four systems interferes, to some degree, with the aerodynamic functioning of the other three, making twelve interferences in all. Dr. Durand has examined the general nature and relative importance of each such source of interference, in the light of the theoretical and experimental knowledge made available in previous volumes. For example, the non-lifting system (fuselage, nacelles, etc.) has an important effect on the lift distribution and drag on the wings, a further effect on the propeller thrust and efficiency and may blanket tail surfaces and controls. Conversely, the lifting system imposes a variable angle between the line of airflow to the propeller and the line of flight, subjects tail surfaces to downwash and turbulence, and changes flow conditions for the fuselage.

In the short section on Aerodynamics of the Airship, Dr. Max M. Munk applies to the airship hull and fins the theoretical methods developed by him for general use in Volume I of the series. His treatment is concise and elegant, as would be expected, and draws from the theory of potential flow, by the use of suitable approximations, conclusions of great significance and value for the practical designer. We find here methods for estimating additional apparent mass, pressure distribution, lateral force, stability of route, etc.

The discussion of the Performance of Airships by Drs. Arnstein and Klemperer is perhaps unique in the literature. Although interest in airships is wide-spread, actual experience with their design and operation has been accessible only to a very limited number of engineers. Such of the results of research and testing as are not "trade secrets" are scattered through professional publications over the past 25 years, in several languages, and are practically unavailable to students. We are indebted to the authors of this monograph for a comprehensive survey of published knowledge, with references to the original publications, and for the inclusion of much unpublished material from their own experience. Airship performance, as a consequence of aerodynamic forces is the classical example of applied theory. The airship designer cannot depend on cut and try methods because of the cost of each unit, and since so few units are built, he cannot depend on empirical rules based on varied experience. Accordingly, he leans on theory and analysis even more than the designer of airplanes. In view of the increasing size and cost of large transport planes, it may be expected that in the near future, the designers of such giants will adopt more analytical methods. For this reason, the section on airships should be of interest to airplane designers.

For example, the resistance to propulsion experienced by a smooth airship hull can be estimated from boundary layer data obtained in flight, but the boundary layer here is no film conception; it is a definite layer a foot thick at forward locations, thickening to a yard farther aft. The airship provides means for the study of velocity distribution in the boundary layer as well as a means for measuring the important effects of length when turning, when encountering gusts, and when flown inclined. As airplanes become larger, these effects on the fuselage and fins will have to be considered. Dynamical stability and control of the airship are discussed by Arnstein and Klemperer by the classical method of "small oscillations" and extended to follow the controlled motion, as when encountering a gust, by an approximate method suitable for step-by-step integration. The airship article constitutes a fairly complete text and it also offers many stimulating suggestions as to method for designers of large aircraft of any type.

M. Barrillon of the French Naval Experimental Tank supplies the section on Hydrodynamics of Boats and Floats. This is obviously not aerodynamics, but the performance of seaplanes involves motion while water-borne, merging gradually into a completely air-borne phase, and consequently cannot be understood without consideration of both phases. Unfortunately, the state of the theory of the planing bottom and the step is such that resort must be had, almost exclusively, to model experiments and comparison with experience. However, Froude's law of comparison permits a correlation of much available data. The author reviews the special operating conditions that govern take-off and landing, stability and control at rest and when planing, and gives a method for computation of time and distance of take-off. The latter is new, at least to this reviewer, and uses a curve of propeller thrust (T) available and a curve of drag (D) plotted on velocity, from rest to take-off. The distance between is, of course, the excess thrust producing acceleration. The interesting construction is the drawing of a line of slope W/g from the origin to the curve T, thence with slope—W/g to the curve D, thence with slope W/g to the curve of T, and so on until take-off is reached. The number of intercepts will equal the number of seconds required for the take-off. On the scale of speeds, the abscissae of the intercepts with T and D give the speeds at the end of one second, two seconds, etc. Each such speed continues for one second (average) and, hence, the sum of the abscissae will give the approximate distance run before take-off.

The final chapter of the volume by Dr. Dryden of the Bureau of Standards is a scholarly review of the problem of heat transfer in the light of present knowledge of aerodynamic theory. It is not yet possible to present a logical development starting from a simple basic law and progressing to the mathematical solution of a typical cooling problem, because of our ignorance of the detail mechanics of eddying flow and of the factors which govern the transition from laminar flow. Dr. Dryden has reviewed the progress of the theoretical attack on the general problem by several independent methods, shows the assumptions necessary to obtain simple formulae, and exposes the basic phenomena. His is the point of view of the physicist, and should prove helpful to engineers working on heat transfer research.

J. C. HUNSAKER.

AERONAUTICAL REVIEWS

These brief reviews of recent articles on aviation subjects are published by the Army Air Corps for the information of its officers, and are printed here each month by permission of the Chief of the Air Corps. The articles listed may not be obtained from the Army Aeronautical Museum Library as these magazines are available to Wright Field personnel only.

Aerodynamics

Sir George Cayley, The Founder of British Aeronautical Science. J. E. Hodgson. Cayley's known contributions to aeronautical science are reviewed. Journal Royal Aeronautical Society, May 1936, page 335.

Test Reports of the Aeronautical Laboratory of the R. Istituto Superiore Di Ingegneria of Turin. Descriptions of the six-component balance with wire suspension and the open-jet return-flow wind tunnel of 600-mm. diameter, and a brief reference to the electric tanks for the study of aerodynamic fields are included in this second series of reports. The results discussed were obtained in research on slotted wings with different shapes and positions of the slots and with flaps of different forms and at different angles, in tests on the Torino "22" to Torino "28" airplane models and on an undercarriage model with three different types of fairing, in experiments intended to determine the interference effect of the propeller on the horizontal tail surface of an airplane, and in motor-car model tests. Fifty-six-page article. Journal Royal Aeronautical Society, May 1936, page 350.

Contribution to the Aerodynamic Study of the Pou-du-Ciel. R. Boname. Results obtained in tests of the Pou-du-Ciel in the small wind tunnel of the Services Techniques are given in a long discussion with a number of curves. L'Aeronautique, March 1936, page 60.

Investigations of Velocity Fluctuations in a Turbulent Flow. F. L. Wattendorf. Mechanism of fully developed turbulent flow between straight parallel walls was studied with the hot-wire anemometer. The apparatus described includes one for measuring the instantaneous value of the component of velocity fluctuation in the direction of a parallel flow of the mean velocity and another for measuring the component of velocity fluctuations perpendicular to the mean flow by means of a double wire of the Burgers type. Journal Aeronautical Sciences, April 1936, page 200.

Speed, an Essential Function of Aviation. M. S. Ducout. Information acquired in the aerodynamics of lifting surfaces shown in formulas of Bernouilli, Kutta-Joukowski, Prandtl, Pistolesi, Pozzi, and Meyer. L'Aerophile, March 1936, page 50.

Airplane Design

Arrangements for High Lift. Captain C. Alippi and A. Eula. Aerodynamic requirements for high lift, operation and characteristics of various high-lifting devices, a comparison of different high-lift devices in regard to decrease in landing speed, increase in stability and controllability at low speeds, increase in glide in free flight, reduction of length of take-off, and effect of high-lift devices on the normal characteristics of flight. Rivista Aeronautica, March 1936, p. 281.

Automatic Stabilization. F. Haus. Gyroscopic directional stabilization is discussed with reference to the principles of the directional gyroscope as well as to the design of the S.E.C.A.T., Sperry, and Smith directional stabilizers. Sperry and Smith devices for the control of ailerons after lateral inclination are explained. Lateral pendulums and the Mazade, S.E.C.A.T., and Siemens equipment for aileron control are described. Concluded. L'Aeronautique, L'Aerotechnique Supplement, March 1936, page 29.

Discovered New Type of Airplane Vibration. "Severe type of vibration, of a kind hitherto unknown in airplanes, has been discovered in a fast high-performance combat plane of the Nation's air forces. L. B. Tuckerman and W. Ramberg of the Bureau of Standards found and cured the fault." Statement with brief explanation. Science News Letter, May 9, 1936, page 301.

Everyman's Airplane—A Move Towards Simpler Flying. F. E. Weick. Distinctive technical features of a two-place pusher monoplane developed for general private use are described with particular reference to the stable three-wheel landing gear, to a means for obtaining lateral stability and control at low speeds with freedom from dangers of the stall, and to a flap arrangement for direct and immediate control of the glide-path angle to facilitate landing steeply at the exact point desired. The possibility of simplifying control by eliminating either rudder or the ailerons, particularly under adverse conditions such as those of precision landings with a cross wind, is taken up. Discussion following presentation of the paper included. S. A. E. Journal, Transactions, May 1936, page 176.

Flutter. M. Rauscher. Formulas for balance coefficients are derived and practical suggestions relating to flight-test technique are given. Charts illustrate the effects of flexural stiffness, c. g. location, and mass on the critical speed of flexural-torsional flutter, dependence of the critical speed of flexural-torsional flutter on the ratio between natural frequencies, and critical speed versus angle of attack for two typical model wings. Concluded. Aviation, May 1936, page 27.

Flying Wing of Charles Fauvel. Official performance tests of the A. V. 10 tailless flying wing, carried out by the C.E.M.A. at Villacoublay. Excellent longitudinal stability at all centering and under all conditions were indicated and it is said that the danger of stalling does not exist. Test results only are discussed without the details of the design itself. Les Ailes, April 9, 1936, page 11.

The Gérin "Varivol" Has Confirmed All the Hopes of Its Inventor in the Chalais-Meudon Wind Tunnel. R. Boname. The high-lift characteristics of the Gérin variable-surface wing are said to surpass those determined for all preceeding designs. Properties of the Handley-Page wing, Fowler flaps, and other high-lift devices tested this year are compared with those of the Gérin wing. Wind-tunnel results are discussed in detail and the design of the "Arbalete" twenty-passenger plane for transatlantic service is described. Les Ailes, April 23, 1936, page 5.

Mean Aerodynamic Centre and Chord. J. R. Crean. Analytical formulas are developed giving the coordinates of the mean aerodynamic center and the length of the mean aerpdynamic chord in the case of a wing plan form whose inner portion is rectangular and outer trapezoidal. Flight, Aircraft Engineer Supplement, April 30, 1936, page 23.

Reflections on the Technical Evolution of Airplanes. L. Breguet. Two- to four-ton gyroplanes to replace the scout seaplanes in naval warfare, and small observation gyroplanes to accompany each battery, as aids to land artillery in finding its range, are predicted. The probable technical evolution and its repercussions on military aircraft of the future from the 1000-ton airplane to the "amphibian gyroptere" are discussed after a review of structural, aerodynamic and engine characteristics of the present day. Revue de l'Armee de l'Air, April 1936, page 394.

Flutter. M. Rauscher. The theoretical and practical aspects of the problem of balancing control surfaces are discussed including balancing of the tail surfaces against flutter involving torsion of the fuselage and flapping of the rudder and elevators, aileron balancing, and the possibility of clamping the movable surfaces in place instead of balancing them. Aviation, April 1936, page 18.

Is There an Ideal Private-Owner Type? Ideal type of aircraft for the private owner according to the views of Lord Willoughby de Broke, Lord Sempill, W. L. Everard, A. J. Richardson, E. W. Walford, G. S. Davison, and Elise Battye. Flight, April 23, 1936, page 430-a.

A New Trailing-Edge Flap. The Short patented controller, or flap, described is mounted in such a way that it may be turned on an axis below the wing so as to extend the trailing edge rearwardly, without breaking the continuity of the upper surfaces of the wing. The flaps will be incorporated in the wings of the new Empire flying boats. Aeroplane, April 8, 1936, page 446.

Retractable Wings. Movable portions of the wing of the Gérin Varivol may be retracted by rolling them up on drums inside the fuselage with a resulting reduction of lifting surfaces from 28 sq. m. to 6.8 sq. m. Results of tests and the advantages of this design are briefly discussed. Aeroplane, Aeronautical Engineering Supplement, April 22, 1936, page 495.

Skin Frictional Resistance and Wake of Models. J. H. Lamble. Effects of changes in "degree of wetting" and "degree of turbulence" on skin frictional resistance and wake of ship models. Tests of various finishes (pure paraffin, various types of surfaces and varnish) are referred to. It was found that the less extent to which the surface is wetted by the water, the greater the tendency towards instability of laminar flow in the boundary layer and the higher the resistance. (Possibly of interest in seaplane design.) Abstract of paper presented before the Institution of Naval Architects. Engineering, April 24, 1936, page 466.

Tests on Ventilation Openings for Aircraft. F. Rokus and T. Troller. Different forms of scoops and hoods for covering airship openings, which were designed for the intake and discharge of air and lifting gas, were measured in the wind tunnel of the Daniel Guggenheim Airship Institute. Drag, flight velocity, air delivery, and built-up pressure were determined. Test set-up, methods, and results are illustrated and described. Results are said to be applicable to other types of aircraft. Journal Aeronautical Sciences, April 1936, page 203.

Two Tests of Tail Surfaces in V. Advantages of V-shaped tail surfaces over the classical types, as shown in model tests. Dimensions of these surfaces mounted on the Mauboussin Corsaire, and the Bleriot control system are described. L'Aerophile, March 1936, page 62.

Airplanes

Some Observations on European Aviation. S. J. Zand. Aeronautical developments in Great Britain, France, Germany, Poland, and Italy are compared with those in the United States, and European transportation problems are outlined. Design of the Potez 62 and Wibault 670 transports, French engines, English geodetic structure, the Pou-du-Ciel (parts of which may be bought in the French equivalent of the five-and-ten-cent store), and the Fiat G-18 transport are briefly reviewed. Journal Aeronautical Sciences, April 1936, page 213.

With the Foreign Builders. Design of the Avro Anson long-range reconnaissance, Caudron-Renault R-570 bomber, Dornier Do-23 bomber, Focke-Wulf FW-58, as a navigation and blind flight trainer and as a training bomber, Junkers JU-86 high-speed transport, Heinkel He-111 commercial, Hawker single-seater with a reported top speed of 320-325 m.p.h., and its Rolls-Royce Merlin engine, Armstrong-Siddeley Mastiff, and the Fokker CX and D-21 fighters briefly reviewed. Aviation, April 1936, page 26.

BELGIUM

Renard-32. Belgian two-seater attack plane and light bomber is powered with a Gnome—Rhone 14-Kirs 870-hp. engine and has a speed of 385 km. per hour at 4,000 m. Five photographs only, one illustrating the machine guns. Les Ailes, April 23, 1936, page 1.

CANADA

Canadian Cruiser. The Noorduyn Norseman described is designed especially to meet conditions of Canadian service, may be mounted on wheels, floats or skiis, and has a high cargo-carrying capacity for low horsepower. Top speed as a landplane is 160 m.p.h. Aviation, April 1936, page 22.

FRANCE

Airplanes of the Société Francaise de Constructions Aéronautiques. Structural parts of the Maillet-Lignel 20 and three views of the "Taupin" are illustrated with specifications of the latter. L'Aeronautique, March 1936, page 48.

Breguet-Dorand Gyroplane. R. Saladin. Helicopter with two coaxial rotors rotating in opposite directions and simultaneously furnishing lift, propulsion and control of the helicopter. The plane has a speed of 100 km. per hour. Description, specifications and three illustrations. Rivista Aeronautica, March 1936, page 371.

The Late-582 Flying Boat for the High Seas. The flying boat described is designed for reconnaissance and bombardment, lands on the high seas, and has a range of 1800 km. and a top speed of 279 km. per hour at 2180 meters. It is powered with three 740-hp. Gnome-Rhone Mistral Major engines. Rivista Aeronautica, March 1936, page 365.

Potez 453. Five photographs only of the Potez 453 pursuit seaplane showing the fairing of the wing around the engine nacelle. Les Ailes, April 9, 1936, page 1.

New High-Speed Tri-Motor 30-Passenger Transports for Air France. The Bloch 300 and the Dewoitine D-620 are described. Rivista Aeronautica, March 1936, page 374.

Parts of the Structure of the Motored Glider S. F. A. N. 1 of the Societe Francaise d'Aviation Nouvelle. Illustration only of structural parts of the single-seater glider of Captain Thoret, which is powered with a Poinsard 25-hp. engine. L'Aeronautique, March 1936, page 48.

The Romano R.90 Pursuit Seaplane. The single-seater, twin-float pursuit biplane described is powered by a 750-hp. Hispano-Suiza 14 H brs engine with a "moteur-canon." Its top speed at 3500 meters is 352 km. per hour and it climbs to 6000 meters in 13 minutes. Rivista Aeronautica, March 1936, page 367.

Variable Incidence. Wings of the Jacquemin airplane are hinged so that the incidence of each can be changed in unison or differentially. The plane is a single-seater high-wing monoplane driven by a 35-hp. Poinsard engine and having a top speed of 150 km. per hour. Brief description. Aeroplane, April 15, 1936, page 474.

GERMANY

The Messerschmitt Taifun Touring Plane. The BFW Me 108-b all-metal (duralumin) low-wing four-place monoplane described is powered with a 250-hp. Hirth 502-b 8-cylinder in-line engine, and has a top speed of 300 km. per hour. Rivista Aeronautica, March 1936, page 374.

Focke-Wulf Fw 58. Focke-Wulf Fw 58 for instruction in blind flying and radio as well as for training in firing machine guns and bombing. Description and six illustrations. Revue de l'Armee de l'Air, April 1936, page 465.

A Glider with a 60 Hp. Engine. The tailless glider "Habicht" described is a compromise between a glider and a sport plane and has a maximum speed of 280 km. per hour. Les Ailes, April 23, 1936, page 11.

GREAT BRITAIN

British Military Aircraft. P. M. Magruder. Composition of the Royal Air Force, the types and makes of planes used in each category, and their approximate performances, are reviewed. This issue includes brief descriptions of fighters, day-bombers, night-bombers, bomber-transports, and torpedo-bombers, with references to a number of experimental fighters and bombers. To be continued. Aero Digest, May 1936, page 21.

Blithe Spirit. Welded steel tubing and sheet aluminum are materials of the Pemberton-Billing Skylark light plane illustrated. Brief reference to construction. Aeroplane, April 22, 1936, page 500. Flight, April 23, 1936, page 442.

For Rapid Peregrinations. Miles Peregrine twin-engined high-speed transport or military trainer. Preliminary data only. Flight, April 23, 1936, page 449.

The Four Winds. 264 m.p.h. is the latest high-speed figure for the Gloster Gladiator which is powered with the 715-hp. Mercury IX engine. Brief reference. Flight, April 16, 1936, page 397.

Modern Light Aircraft Reviewed. Nineteen private-owner, club, and school types of light aircraft on the British market are illustrated, and their features described from the viewpoint of the amateur pilot. Aeronca, Airspeed, Autogiro, Avro, British Aircraft, B.A.C., C.L.W., D.H., Heston Phoenix, Hillson Praga, Miles, Monospar, Marendaz, Parnall, Pou-du-Ciel, Percival, Perman, Short Scion, and the Saro Cutty Sark are included. Flight, April 23, 1936, page 415.

Standardizing the Cadet. Wing stagger, extra wing bracing, narrower fuselage and cockpits, and castoring tail wheel are new features of the Avro 643, or standard Cadet, training biplane described in detail. Aeroplane, April 15, 1936, page 466.

HOLLAND

Fokker D-XXI. New Fokker D-XXI pursuit powered with a Bristol Mercury VI-S engine developing 645 hp. at 4,725 m. Illustration only with brief reference to performance and armament in the caption. Les Ailes, April 9, 1936, page 6.

ITALY

New Types of Planes. The new planes placed into service by Italy are the P.16 monoplane bomber, S.81 high-speed bomber, and the Cant 24 AR, RO 37, RO 41, and RO 43 seaplanes. Brief references to performance and load of the first two. U. S. Naval Institute Proceedings, May 1936, page 741.

JUGO-SLAVIA

The Mitrovitch "M. M. S.—3" Taxi-Airplane. Three-place touring airplane serving as a flying model for the Jugoslavian Company "Aeropout." The plane is powered with two Pobjoy Niagara 90-hp. engines and has a cruising speed of 215 km. per hour. Les Ailes, April 23, 1936, page 3.

U. S. A.

Arrow Model F. The plane described is the most conventional of the Air Commerce Bureau's development projects, and is powered by a Ford V-8 engine. Conversion of the Ford engine and specifications of the airplane are discussed. Aviation, May 1936, page 36.

Foreign Aviation. A two-seater Curtiss A12 "Shrike" of the 13th Attack Squadron is illustrated with removable skiis, and a reference is made to the winter maneuvers. A photograph of the new Curtiss S.O.C.-1 seaplane for the Navy is shown on the following page. Les Ailes, April 16, 1936, page 8.

Hammond to Bureau. Performance and modications of the newest Model Y Hammond light plane designed for the Bureau of Air Commerce as part of the later's light-plain development program. Aviation, May 1936, page 31.

Ford-Powered. Campbell all-metal two-passenger three-wheel pusher monoplane described was designed around the standard Ford V-8 engine. It has a top speed of 120 mph, and is said to be easy to land and to have no spinning tendencies. Aviation, April 1936, page 23.

Grumman Fighter. The latest in single-seaters delivered to the Navy by Grumman. Very brief description with reference to machine guns and a reported top speed of 240 m.p.h. Aviation, April 1936, page 23.

Inside an Amphibian. Fairchild 91 amphibian is briefly described with a diagram of the layout. Scientific American, May 1936, page 267.

Perforated Flaps. Latest Northrop attack delivered to the Air Corps for test carries a new type of perforated flap to eliminate buffeting." Brief reference to flap design with photograph. Aviation, May 1936, page 37.

Transatlantic. Fifty-five-ton super-seaplane planned by Sikorsky varies somewhat in outward appearance from usual Sikorsky practice and is designed to sleep 48 passengers. Interior arrangements and predicted performance briefly discussed. Aviation, May 1936, page 47.

U. S. S. R.

A Soviet Glider of Rubber. The pneumatic rubber glider described is made entirely of light rubber-coated linen, and can be folded into a special bag 1 m. x 1 m. x 0.50 m. in size when deflated. It weighs only 77 kg. and can be inflated by means of an air pump in 15 to 20 minutes. Description, specifications and drawing. L'Aerophile, March 1936, page 64.

A Train of Gliders at High Altitudes. Russian high-altitude flight of a twin-engined airplane with two two-seater gliders and one single-seater glider. The gliders are equipped with navigation instruments and mounted on skiis. Brief description. Les Ailes, April 16, 1936, page 9.

Airplane Performance

System for Determination of Minimum Velocity. C. Adrian. French methods of testing the minimum velocity of an airplane are described. Rivista Aeronautica, March 1936, page 384.

Stress Analysis and Structures

Great Circle Aircraft Construction. Geodetic method of construction developed by B. N. Wallis of the Vickers Company in a simple, brief explanation. Scientific American, May 1936, page 266.

Lamé's Theory of Thick Cylinders and Thick Spherical Shells. C. Harvey. Lamé's theory is criticized and the statement is made that the measure of strain is a ratio, not a magnitude, and axial strain must therefore be independent of the length of the cylinder. Engineering, April 17, 1936, page 414.

Skin Thicknesses. Thicknesses of plating used on the H. E. 70 and H. E. 111 fuselages as well as on an unidentified fuselage are illustrated and briefly explained. Aeroplane, April 22, 1936, page 500.

Stressed-Skin Construction in Germany. B. S. Shenstone. Basic principles of stressed-skin construction and their application with special reference to the structure of the Heinkel H. E. 70. Loads which an element of the shell can resist, the application of loads in shell structures, and the buckling of shells are discussed by H. Wagner, in the first part. H. Hertel, in the second part, takes up shells with longitudinal and lateral stiffeners and with cut-outs, weights of various parts of the H. E. 70 fuselage, the time required for constructing them, and three ways of plating the fuselage. Summary of two papers presented before the Vereinigung fuer Luftfahrtforschung. Aeroplane, Aeronautical Engineering Supplement, April 15, 1936, page 470.

Tests on the Stress Distribution in Reinforced Panels. R. J. White and H. M. Antz. "Shear-lag," or the tendency of stresses in the covering of stressed-skin aircraft structures to be concentrated near certain stiffeners and to be very small near others. In the tests described the loads are applied to the edge stiffeners at one end of the test panel and a procedure is developed for determining the loads carried by the intermediate stiffeners. Journal Aeronautical Sciences, April 1936, page 209.

The Stressing of Monoplane Wings. The graphical method of treating a two-spar wing with stiff covering and parallel or non-parallel spars, developed in the March 26 issue, is extended to cover the case when the "R" line is not straight, for both parallel and non-parallel spars. Flight, Aircraft Engineer Supplement, April 30, 1936, page 27.

Variations of the Rigidity Modulus with Changes in Applied Stress. G. M. Francis. An attempt to determine by an interferometer method whether or not any variations occurred in the rigidity modulus, similar to those which occurred in Young's modulus, as found in D. K. Froman's experiment. Physics, April 1936, page 160.

Metals

The Deformation, Recovery and Recrystallization Behavior of Metals. R. H. Hobrock. Grain growth, unintentionally caused by the forming, annealing, heat-treating and welding processes, and conditions producing grain growth are considered. The influence of large grains on the static and dynamic strength properties is illustrated, and precautions against growth are suggested. Results of the author's own investigations on one of the strong wrought aluminum alloys commonly used in aircraft are also included. Journal Aeronautical Sciences, April 1936, page 191.

Modern Physics and the Strength of Metals. Fracture of metals under static and fatigue stressing, hitherto believed widely different in effect, is associated with identical changes in the crystalline structure, that is, the formation of crystallites accompanies fracture. Editorial discussion of paper presented before the Royal Aeronautical Society by H. T. Gough and W. A. Wood. Engineer, April 24, 1936, page 441.

STEEL

Low-Alloy High-Tensile Steels. A. B. Kinzel. Design fiber stress determination, too high a ratio of yield to tensile strength, alloys for uniform strength and ductility, strength achieved with low carbon content, classification of new alloy steels, influence of carbon on ductility, same ultimate strength for same carbon content, weldability from the engineering standpoint, low-carbon steels insensitive to rapid cooling, corrosion resistance, and heat treatment are discussed. Crankcase for a "10-cylinder 450-hp. radial Diesel," fabricated in two halves and welded together, is illustrated. Paper presented before the American Welding Society. Iron Age, April 23, 1936, page 32.

Steel Sheets and Strip for Aircraft. New and revised British Standard Specifications—outline only. Engineer, April 24, 1936, page 438.

Airships

Air and Water. Largest dirigible in the world, planned by Goodyear-Zeppelin engineers, will be 850 ft. long and 145 ft. in diameter, and is designed for transatlantic service. Brief reference. Engineer, May 1, 1936, page 463.

"Hindenburg"—Latest and Largest Zepplin. Construction, control, passenger quarters and engines are briefly covered in a general two-page description. Aero Digest, May 1936, page 42.

The Zeppelin LZ 129 "Hindenburg." Further details of the Hindenburg with structural drawings. A second article entitled "Without a Roll to Rio" describes the first flight of the airship to Brazil. Aeroplane, April 29, 1936, page 525.

Propellers

Propeller Advances. F. W. Caldwell. Subject on propellers outlined to provoke discussion by other speakers. Particular reference is made to interrelation of propeller and power plant in regard to aerodynamics and resonance vibration, and to materials and stresses. Extensometers for measurement of vibration stresses are named. Journal Aeronautical Sciences, April 1936, page 219.

Propeller Brakes. Cases where a propeller brake is necessary, the design of a propeller with remote control by hydraulic pressure, and an arrangement of the blades to annul the torque of autorotation. Brief discussion. L'Aeronautique, March 1936, page 66.

A Banner Year for Aviation. Army Air Corps is considering proposals for the design of tandem propellers driven by the same engine but rotating in opposite directions so that torque effects are eliminated. Statement in predictions of future developments made by J. Lederer. Scientific American, May 1936, page 278.

An Automatic V. P. Airscrew. Schwarz two-position hub with completely automatic operation. It is said that the propeller may be employed on airplanes fitted with a gun firing through the propeller axis, and that it may be mounted on the propeller shaft in the same way as an ordinary fixed-blade propeller, requiring no alteration to the engine shaft nor fittings on the aircraft or engine. Aircraft Engineering, May 1936, page 128.

Propeller Servicing Equipment. A device for straightening and pitching metal propellers developed by the Northwest Air Service. Few details. Aero Digest, May 1936, page 52.

Testing of Controllable-Pitch Propellers. G. T. Lampton. Test methods and equipment successfully used both in the development and in the testing of the Lycoming-Smith propeller. Vibration tests, conducted in accordance with the U. S. Army Air Corps technique, form the largest part of the test work. The company and several governmental agencies, notably the Air Corps, are now working on instrumentation and technique for the detection of resonance under actual operating and flight conditions. A. S. M. E. Transactions, May 1936, page 263.

Variable-Pitch Airscrew Performance. W. H. Savers. A method is developed for dealing with the prediction of variable-pitch propeller performance with modern supercharged engines. The author derives expressions for engine regime conditions, not in terms of the actual torque coefficient Kq, but in terms of Kq/Kqo which is a pure number with a value independent of the units in which power, engine speed, and density are expressed, so long as they are all consistent. The method is applied to the case of the two-position propeller and to an estimation of static thrust. Long article with four charts. Aircraft Engineering, May 1936, page 121.

Engines

900-Hp. Aero Engine for Empire Flying Boats. Bristol Pegasus Xc 9-cylinder radial engines with new design of cylinder and head giving a 40 per cent increase in cooling area. Changes in design of cylinders and pistons, as well as the reduction gearing, fuel used, carburetors and ignition are described. Engineering, April 24, 1936, page 450.

Fitting Aero Engine Developments to Tractor Needs. Developments in the Wright Cyclone which have raised the output to a maximum of 1000 hp. Brief abstract of paper presented before the S.A.E. at Milwaukee by R. W. Young, with an illustration of manifold pressure curves. Automotive Industries, April 25, 1936, page 600.

Light Aircraft Power Units. Fifteen British engines available for the private owner, are briefly reviewed including the A.B.C., Aero, Alta, Armstrong-Siddeley, British Anzani, British Salmson, Carden, Cirrus-Hermes, Coventry Victor, De Havilland, Napier, Pobjoy, Scott, Villiers-Hays, and Wolseley engines, with a list of engine accessories. Flight, April 23, 1936, page 438.

Lightweight Power. The Amherst Villiers Maya 4-L-318 aircraft engine described has four inverted air-cooled in-line cylinders and is designed to run for 1000 hours between overhauls. It will be rated at 120 hp. normal at 2300 r.p.m. and at 130 hp. maximum at 2600 r.p.m. The all up weight is only 275 pounds. Long well-illustrated description. Aeroplane, April 22, 1936, page 496. Flight, April 23, 1936, page 427.

Whirlwinds DeLuxe. Two new engines in the private-owner range with transport features, namely the 7-cylinder Whirlwind 320 rated at 320 hp. and the 450 rated at 450 hp. Outstanding features only are described. Aviation, April 1936, page 22.

Pratt & Whitney Twin-Row Engine Delivers 1160 Hp. at 2700 R.P.M. The Model 1830 Twin Wasp weighs 1250 lb., is rated at 1000 hp. at 2400 r.p.m., and has a fuel consumption of 0.45 lb. per b.hp.-hr. Among the new features referred to are complete automatic valve-gear lubrication, automatic mixture control, enlarged cylinder-head cooling fins, and a new pressure baffling system. Aero Digest, May 1936, page 41.

Two-Row Engines Come into Their Own. C. W. Deeds. Development of the Pratt and Whitney two-row radial and distinctive features of the Twin Wasp and Twin Wasp Junior. U. S. Air Services, May 1936, page 19.

ACCESSORIES

Steam-Type Engine Starter. "Steam-type airplane-engine starter now being tested by W. E. Huffman of the miscellaneous equipment laboratory at Wright Field" was designed for use in extreme cold weather. Brief description with reference to a photograph which does not appear in the article. Aero Digest, May 1936, page 52.

Synchronizing Engines. Synchronization of the engines of multi-engined aircraft to a fraction of 1 r.p.m. slower or faster is obtained by means of the engine synchronizer described which is used by Central Airlines. Brief description. Aero Digest, May 1936, page 52.

Automatic Mixture Control. R. W. Young. A sylphon tube controls the mixture furnished to Wright Cyclone engines by the Bendix-Stromberg carburetor. An economizer valve, located in one of the two carburetor float chambers, is interconnected with the throttle and provides an excess fuel flow for the upper power range to the two adjacent venturi. An installation diagram of the carburetor with automatic control, and curves of flight propeller-load fuel flow and of specific fuel consumption are included. Long abstract of paper presented before the S. A. E. Automotive Industries, May 2, 1936, page 642.

Converts Gasoline Engine to Run on Fuel Oil. Equipment developed by the Nuway Engineering Corporation comprises an oil preheating unit and a thermostatically controlled hot air unit. Brief description. Automotive Industries, April 25, 1936, page 596.

Getting Rid of Vibration. The Renaux engine mount is a new form of elastic suspension applied to the radial engine, and is said to have the shock-absorbing properties of the pneumatic tire. A system of links is so devised that any vibrations which tend to turn the mounting ring about its center tend to deform the tires sideways. Brief description. Aeroplane, April 22, 1936, page 501.

An Interesting Control System. Push-pull movement of the Teleflex control system is transmitted via a flexible cable. It is applied to the operation of carburetor controls, trimming controls, camera operation, torpedo setting, gun-ring control, and wheel-brake operation. Brief illustrated description. Flight, April 16, 1936, page 410.

Low Drag Radiators. Gallay System "E" supro-nickel radiator and Dual Stage oil cooler for the Fairey Battle two-seater bomber. Brief illustrated description. Aeroplane, April 22, 1936, page 511.

Engine Design and Research

Cowling and Cooling. Solution of "baffling" problems, the advent of controlled cooling, and the cowling and cooling of "H"-type engines. N.A.C.A. cowling and baffling of the Pratt & Whitney and Wright two-row engines, and the cowlings fitted as standard on the Armstrong-Siddeley Panther and Tiger two-row radials are described. Cowling the Napier Rapier and Dagger "H" type air-cooled four-bank engines is explained with a diagram illustrating the cowling and cooling arrangement developed for the 24-cylinder Dagger. Cowling of small in-line engines is also taken up. Concluded. Flight, April 30, 1936, page 454.

Cylinder Wear in Diesel Engines. G. D. Boerlage and B. J. J. Gravesteyn. Delft continuous method of measuring cylinder wear, correlation with other wear measurements, weight of ash per half hour and ash percentage, iron content in the ash, fuel and oil wear, and wear under different loads are discussed and the effects of fuel ash and

acid content, of cooling-water temperature, and of additions of water on wear are pointed out. S. A. E. Journal (Transactions), May 1936, page 197.

Cylinder Wear in Gasoline Engines. C. G. Williams. Effects on cylinder wear of mixture strength, composition of the lubricant, piston clearance, radial ring pressure, and the ring width were determined in the research described. Report of the Research and Standardization Committee on Cylinder Wear of the Institution of Automobile Engines. S. A. E. Journal (Transactions), May 1936, page 191.

The Effect of Gas Pressure on Piston Friction. M. P. Taylor. Friction increased approximately as a linear function of the pressure and the running speed, the effect of jacket-warm temperature on piston friction was marked, and about a fourth of the rate of increase in friction with pressure was due to gas pressure behind the rings, it was found in the M.I.T. research described. S. A. E. Journal (Transactions), May 1936, page 200.

An Engine with Double Connecting Rods. In the Maillet engine described four cylinders have their four pistons arranged in a cross and four independent crankpins form another cross staggered at 45° to the first, all lying in the same plane. Each piston is joined by two connecting rods to the two adjacent crankpins, each crankpin carrying one of the pinions of the reduction gear and driving the large wheel solid with the propeller shaft. Motion of the piston is sinusoidal. In comparison with the normal engine a longer combustion period and a shorter scavenging period are obtained. The design of a two-cycle Maillet carburetor engine is described which operates two propellers in opposite directions and has four crosses of four cylinders each. Two superchargers are included and 1,280 hp. is said to be obtainable with such a design. Les Ailes, April 16, 1936, page 5.

Ice and What is Being Done About It. S. P. Johnston. Means of preventing ice formation in carburetors, improvements in attaching wing de-icers, and development of the propeller slinger ring. Disadvantages of applying heat to the carburetor intake air are pointed out and three projects are discussed which were sponsored by the Bureau of Air Commerce, two involving extensive redesigning of carburetor principles, and a third the use of non-freezing fuel mixtures. The Bendix-Stromberg design being tested at the Naval Aircraft factory, the Chandler-Groves carburetor, and development in alcohol-fuel mixtures are described. Reference is made to the fact that research on direct injection of fuel into the engine cylinder is being carried on at Wright Field and N.A.C.A. laboratories. Aviation, May 1936, page 15.

Cowling and Cooling of Air-Cooled Engines. Past difficulties in reconciling efficient cooling and low-drag cowling, and the introduction of modern methods. Bristol cowlings, helmets, the Siddeley long-chord cowling, and a combination of helmets with modern long-chord cowling on the Avro Anson are illustrated. To be concluded. Flight, April 16, 1936, page 400a.

Cross Linerless Light-Alloy Cylinder. Wear of the cylinder bore is claimed to be much less in the design without liners than with conventional cast-iron blocks or liners. Aluminum cylinders without liners and aluminum pistons used in engines prouced by R. C. Cross of England are briefly described. Automotive Industries, May 2, 1936, page 647.

The Reverse Scavenging of Two-Cycle Carburetor Engines. K. Karde. Methods of scavenging two-cycle engines are compared. Tests show that the evaluation factor depends on the final expansion temperature, and on the form of the combustion chamber, as well as on the compression ratio. As a result of the poor design of the combustion chamber, the compression ratio and the rate of combustion are much lower with transverse flow than with the new scavenging method described, and the final expansion temperature is higher. V.D.I., April 4, 1936, page 428.

A Survey of Engine Development. C. L. Lawrance. The two-cycle type of Diesel is the only type considered worthwhile. Very brief abstract. Journal Aeronautical Sciences, April 1936, page 219.

Engine Testing

Cetane Rating of Diesel Fuels. P. H. Schweitzer and T. B. Hetzel. A diaphragm in the cylinder head, a phonograph "pick-up," a short stiff wire transmitting the motion of the diaphragm to the pick-up, a thyratron relay, and a neon lamp protractor were used for determining the moment of ignition in the tests described. A similar pick-up is used for indicating injection timing. With this apparatus and the "fixed-ignition-lag" method, Diesel fuel testing in the C.F.R. engine is said so to be simplified that seven to eight fuels can be tested in an hour. Discussions following presentation of the paper are also included. S. A. E. Journal, May 1936, page 206.

The Measurement of Ignition Delay in Oil Engines. E. Glaister. Methods of Boerlage and Broeze, and Blache for determining the crank-angle at which fuel injection begins, and a method of measuring ignition delay directly are criticized. The development of a means for recording the fuel-injection period on the same photographic plate as the cylinder diagram is described. A thyratron tube was tried out to provide a more actinic light source with a satisfactorily rapid response, and a Pointolite lamp was used as a light source for taking indicator diagrams. Engineering, May 1, 1936, page 469.

Engine Production Methods

Aluminum for Plymouth Pistons. Operations in the manufacture of aluminum pistons with elliptical skirts. Long abstract of paper presented before the S. A. E. by E. S. Chapman. Automotive Industries, May 2, 1936, page 639.

Fuels and Lubricants

Alcohol in Gasoline Discussed as an Engineering Problem. G. G. Brown. Blending of alcohol with gasoline for use as a motor fuel. Test results discussed and the conclusion reached that the practice is most uneconomical at present. Abstract of paper presented before the Western Petroleum Refiners Association. Oil and Gas Journal, May 7, 1936, page 51.

Rating Aviation Fuels in Full-Scale Aircraft Engines. C. B. Veal. Degree of correlation between octane-number determinations made by the C.F.R. motor method of rating motor fuels, and the behavior of widely different types of aviation fuel in representative full-scale aircraft engines. Test results obtained by Wright, Pratt & Whitney, Lycoming, and the Bureau of Standards are analyzed. Report of the Cooperative Fuel Research Committee. S. A. E. Journal (Transactions), May 1936, page 161.

Role of Iso-Pentane in Manufacturing 100 Octane Aviation Gasoline. F. B. Neptune, H. M. Trimble and R. C. Alden. Stimulating influence of the U. S. Army Air Corps has precipitated a feverish interest in 100-octane-number gasoline and has created an impatience to realize the advantages now apparent. Experiments are described which were undertaken in the Research Department of Phillips Petroleum Company to demonstrate the role of iso-pentane in the manufacture of 100-octane gasoline. Vapor pressure, distillation and sulfur data of the composite base, anti-knock data of blends and composite base, and results obtained by "iso-pentanizing" an iso-octane blend are given in tables. Oil and Gas Journal, April 23, 1936, page 26.

Instruments

Altithermometer or Climb Indicator. Criticism of the Rousselle altithermometer previously described, and comparison with a climb indicator with vanes which is said to be very sensitive for measuring the instantaneous speed in climb or descent. Advantages for use on gliders are pointed out. Les Ailes, April 16, 1936, page 4.

Autosyn Remote Indicating System. H. G. Boynton. The Autosyn Pioneer transmitting and indicating unit consists of small self-synchronous motors and is applicable to engine gauges, tachometers, fuel-flow indicators, fuel-quantity indicators, position indicators, and radio equipment. Any movement of the rotor of the transmitting motor is instantly duplicated by a corresponding movement of the indicating-motor rotor. Two-page description. Aero Digest, May 1936, page 48.

Eclipse Items. New Eclipse synchroscope designed for synchronization of engines on multi-engine airplanes, and a flow meter for measuring the instantaneous rate of flow of fuel. Few details. Aviation, May 1936, page 43.

Fuel Gauges. The Short and Mason A.G.O. flowmeter described makes use of the fact that the pressure in the fuel line between the pump and the carburetor, or the tank and the carburetor, varies according to the velocity of the fluid in the pipe line. A contents gauge is also briefly described. Aeroplane, April 29, 1936, page 539.

Instrument Illuminator. A new Moon-Glow-type aircraft instrument illuminator and map light produced by Fairchild Aerial Camera Corporation. Few details. Aero Digest, May 1936, page 52. Aviation, May 1936, page 43.

Morane-Saulnier Recorder for Determining the Forces Exerted by the Pilot on the Control Surfaces. R. Rabion. A continuous force of 8 kg. on the stick was considered intolerable by the pilot, it was indicated in the first tests of the recording device described. A diagram of the apparatus, installation on the Morane-Saulnier M.S.–335, and records obtained with the apparatus in this installation are illustrated. Les Ailes, April 9, 1936, page 5.

Pioneer Compass. Type 941 compass designed to meet an Army requirement for small light-weight instruments capable of withstanding violent maneuvers. Few details. Aviation, May 1936, page 44.

A Real Flying Showroom. Some of the 50 instruments and equipment marketed by Smith's Aircraft Instruments and carried on the D.H. Dragon flying showroom are listed. Flight, April 30, 1936, page 463. Aeroplane, April 29, 1936, page 535.

Askenasy Sonic Altimeter. G. Jacquet. Principles of a recently patented French method for sounding by echoes to determine the height of an airplane above the ground. Detailed description with particular attention to the "antifading" arrangement. Critical opinions on the system are also given. Revue de l'Armee de l'Air, March 1936, page 348.

The British Automatic Pilot for Aircraft. G. R. M. Garratt. The automatic pilot described is said to have been developed at the Royal Aircraft Establishment primarily for the highest possible stabilization of aircraft for military purposes. The form of motion resulting from a disturbance, and the manner in which the control surfaces of the aircraft are used to correct it are considered. The air-compressor installation, construction of rudder and elevator control, arrangement to precess the gyroscope in the azimuth, operation of pitch control, maintenance of pitch datum, and tilting of the gyroscope axis are discussed in the first article.

The second covers aileron control, gyro-vertical mechanism, control during a turn, centralizers, one of which is fitted to the rudder and elevator control and one to the aileron control, and the preliminary operation of controls. Long detailed description. Engineer, April 17 and 24, 1936, pages 419 and 430.

Aerial Photography

Photogrammetric Measurements from the Airplane. W. Block. Methods, radial triangulation, accuracy attained, conjunction of successive photographs, and the use of the Aeromultiplex in the evaluation of photographs. Extent of application in Denmark, Norway, France, Canada, Hungary, Switzerland, and Germany is also briefly reviewed. V.D.I., April 4, 1936, page 426.

Theory and Practice of Aero Precise Traversing and Aero Leveling. O. V. Gruber. Brief abstract from Bildmessung and Luftbildwesen No. 10, 1935, page 127. Zeitschrift fuer Instrumentenkunde, April 1936, page 176.

Radio

Radio Compass. J. P. Gaty. Two types of radio-compass installation and a method of checking position along an airway-beacon track are described and illustrated. To be continued. Aviation, May 1936, page 24.

Radio Equipment. All of the 1150 combat planes in the Air Corps are now fully equipped with radio communication units. Brief reference to report of the U. S. Signal Corps. Aero Digest, May 1936, page 60.

Eliminating Doubt in Direction Finding. H. H. Bellini. In the described arrangement for eliminating doubt in direction finding, the action of a vertical antenna is superposed on the action of the frame, the most favorable diagram being obtained by that of the cardioid. L'Onde Electrique, April 1936, page 254.

The Robinson Altimeter with Automatic Regulation by Radio. Improvements to the system of signalling by radio to aircraft, patented in France by J. Robinson. The transmitter is modulated to a determined frequency which is connected with the barometric pressure at the location of the transmitter so that the note of the modulation varies with the pressure. The receiver in the airplane is analogous to a radio telephone with a high-frequency amplifier and a detector, amplifying the current the frequency of which is precisely that of the modulation so that changes in barometric pressure at the transmitting station are registered on an indicator in the plane. Equipment for indicating the differences in altitude of two airplanes is also described. Revue de l'Armee de l'Air, April 1936, page 471.

A New System for Blind Landing of Airplanes. A. Ettinger. Control of landing maneuvers from the ground is made possible with the new system developed by the authors. Instead of transmitting aerials fixing the direction and glide path, there are directionally sensitive receiving aerials. The method is described and the blind-landing method of the Army Air Corps, used by the Bureau of Air Commerce, the Dunmore and Diamond system, and the Lorenz method are reviewed. Proceedings, Institute Radio Engineers, May 1936, page 751.

The Use of Radio on Touring Planes. Conditions governing the design of a radio for the private flier are discussed by C. Fauvel, an officer in the Armee de l'Air. Les Ailes, April 9, 1936, page 4.

Deviations of Direction Finders on Airplanes. E. Fromy. The qualitative analysis of the disturbing effects produced by metallic fuselages on direction finders is continued from the February issue with formulas developed for the disturbing circuits and their mutual reactions. The concluding article gives the experimental verifications of the theory. L'Onde Electrique, March and April 1936, pages 168 and 245.

Direction Finder for Airplanes. Captain A. Lidonnici. Function of each part of the direction finder, and precautions to be taken in mounting them, as well as theoretical and practical considerations for the compensation of the direction finder in operation. Rivista Aeronautica, March 1936, page 319.

Electricity Extraordinary. Damage done to aerial and tube, fuselage fabric and other parts of the airplane when flying through a cloud. It is assumed that, because of some difference in potential, possibly between the cloud into which the machine flew and another cloud into which the trailing aerial was dipping, a small current of high voltage ran along the aerial and fused it. Brief discussion. Aeroplane, April 22, 1936, page 489.

Flying the Pacific by Radio. Radio facilities developed by Pan American Airways for communication and for direction finding, which include complete transmitting and receiving equipment in 127 land stations, 138 planes, and 22 radio compass direction finders. The communication equipment of the ground stations and planes, operating procedure, radio direction-finding apparatus, and the P.A.A.-Adcock direction finders are described. Electronics, April 1936, page 7.

New Empire Flying Boats. Radio equipment for the giant flying boats for Imperial Airways. One receiver with separate tuning controls is used for communication and direction-finding work. Provisions are made for working on short, medium and long wave-lengths and three separate aerials are available. Wireless World, April 24, 1936, page 409.

Radio in Air Corps "Flying Flagship." Two radio transmitters installed in the new 205-mile-an-hour Douglas twin-motor flying headquarters of General Andrews. Illustration only with long caption. Electronics, April 1936, page 34.

Meteorology

Air Mass Analysis. W. H. Wenstrom. Upper-air soundings, an analysis of air masses from the soundings, the various types of American air masses summarized from an M.I.T. study, and the causes of bumps, rough air, and turbulence. Continuation. Aero Digest, May 1936, page 28.

Scientists Describe Results Obtained in the Stratosphere. Possible causes for the unexpected air conductivity found above 60,000 feet, and composition of the stratosphere air. Brief review of results obtained in the stratosphere flight of the Explorer II. Science News Letter, May 9, 1936, page 299.

Scientific Results of the World-Record Stratosphere Flight. Captain A. W. Stevens. Results obtained during the National Geographic Society-U. S. Army Air Corps stratosphere flight. The discussion is covered under the following headings: region of the cloudless sky; why scientists must go aloft to study cosmic rays; protection of the ball from rays penetrating the interior and ionizing the gas; sky-high laboratory with a heavy load; where cosmic rays abound; making a ray take its own picture; where the sunlight is brightest; how ozone protects life on earth; an electric fan at 81 below zero; a precious twelve gallons of stratosphere air; spores survive where man could not live; a midnight vigil in a laboratory; fungi important to life of man; how the sky, sun and earth looked at top of the flight; where the deeper blue begins; photographing objects invisible to the eye; and new facts on upper air current. Other new facts added by the flight are listed and a photographic supplement shows the lateral curvature of the earth as photographed at an elevation of 72,395 feet. National Geographic Magazine, May 1936, page 693.

Commercial Aerial Navigation Across the North Atlantic. M. Bellonte. Five possible air routes across the North Atlantic, the general meterological situation, meterological protection, and methods of navigating and piloting required for such a service are discussed in a long article. L'Aerophile, March 1936, page 51.

Cosmic Rays Investigated in Airplane Flights. Ionization effect of the cosmic rays rises as a function of the altitude. Brief abstract of paper presented before the National Academy of Sciences by R. A. Millikan. Science News Letter, May 2, 1936, page 284.

Abstracts, St. Louis Meeting, December 30–31, 1935. "Some Intercorrelations between Climatic Variables in the Corn Belt," J. K. Rose. "Influence of Sea Temperature Anomalies on Seasonal Rainfall and Temperature Departures in the Southwest," C. J. Bollinger. "New York University Institute of Aeronautical Meteorology—Its Structure and Problems," J. E. Woodman. "Wind Behavior Above the 15,000-Foot Level over Northern New York City, March–October, 1935," S. M. Serebreny. Bulletin, American Meteorology Society, April 1936, page 116.

Air Forces

FRANCE

French Naval Aviation. Its Organization in the Mediterranean. Captain Delahaye. French naval aviation in time of war, aviation in naval operations, observation and exploration missions, pursuit and bombardment offensive missions, landing planes on aircraft carriers, naval air stations, and the naval theatre of the Mediterranean are discussed with an organization chart of control in the Mediterranean. Revue de l'Armee de l'Air, March 1936, page 252.

A Program for 1936–1942. A. Langeron. A program for the development of French Naval Aviation in the next six years. Les Ailes, April 9, 1936, page 8.

U. S. A.

4,000 Planes. Bill approved by the House of Representatives providing for 4,000 planes, and a reserve personnel of 1,350 pilots on active duty is briefly referred to as well as another measure to change the promotion system now in effect in the Army Air Corps. Aero Digest, May 1936, page 60.

Bids and Orders. "Air Corps spends $5.6 million for engines, asks new bids on aircraft." Discussion of bids and the Wright and Pratt Whitney engine orders. Aviation, April 1936, page 42.

G. H. Q. Air Force Winter Test and Maneuvers. Special equipment and clothing tested under severe cold-weather conditions in the winter maneuvers. Brief discussion. Army Ordnance, March–April 1936, page 305.

Aeroneurosis, Disease of Airplane Pilots, Reported. Profound emotional stress resulting from the accident hazards of flying and from economic and social insecurity is said to be the chief cause of aeroneurosis. Captain Armstrong's report in the Journal, American Medical Association, April 18 is discussed briefly. Science News Letter, May 9, 1936, page 300.

Bids for Pursuits. "A second try to meet Air Corps Specifications for single-seat pursuits." Curtiss, Chance-Vought, Seversky and Consolidated bids given. Aviation, May 1936, page 54.

Four Model Pursuit Ships Received by Air Corps. Curtiss, Chance-Vought, Seversky, and Consolidated model pursuit ships received for testing. Brief reference. U. S. Air Services, May 1936, page 34.

Results of Winter Maneuvers by G.H.Q. Results obtained in the tests of clothing and equipment during the New England Winter Maneuvers. Very brief discussion. U. S. Air Services, May 1936, page 21.

Two for the Navy. Vought scout bomber and Douglas torpedo bomber ordered by the Navy. Brief reference to design of the Vought XSBZU-1. Aviation, May 1936, page 33.

Air Warfare

Air Strategy. Lt.-General N. N. Golovine. "Lack of strategic ideas and too much attention paid to technical achievements" are the author's criticisms of the air doctrine adopted by the United States Army Air Corps. Characteristic errors to be found in the air doctrines adopted by other nations, are classified as follows: Too much theory: the resulting organization is not in conformity with the original doctrine—example: Douhet's doctrine and the Italian Air Force. Political and strategic aims not clearly defined—example: Great Britain. Technical progress overlooked and too much attention paid to military theories—example: France. Germany and the Soviet Union are said to be the only countries which have, until lately, worked out practical air doctrines. General Douhet's doctrine is criticized with the above conclusions. Equipment and organization of the Royal Air Force, as well as the air forces of France, Germany, U.S.S.R., Italy, and the United States are also discussed in the first chapter. The other two chapters are devoted to problems of British air strategy, technical progress in aircraft, engines and armament, and armament schemes. Forty-four page discussion. To be continued. Royal Air Force Quarterly, April 1936, page 169.

Air Warfare. General G. Douhet. Principles of air warfare. Summary of the first part of a much criticized book by the Italian general, Douhet. Lessons taught by past wars, capabilities of the airplane, and the force of logic are pointed out. Objectives of air attack, mastery of the air and national defense, question of an air army or air arms, and consequences of the mastery of the air, are discussed and material resources of the air army in regard to bombers and com-

bat airplanes, aerial cruiser and scout, and civil and military aircraft are taken up. Technique of aerial battle covers the capacity of the air offensive, weakness of the defensive, and employment of the air army. Conclusions reached are also summarized. Royal Air Force Quarterly, April 1936, page 152.

Bombardment in Diving or in Horizontal Flight. Chances for attaining the object of an attack by bombing in a dive are compared with the opportunity offered by bombing in horizontal flight. The effect of surprise, rapidity of attack, value of anti-aircraft defense, and the increase in the precision of firing in a dive due to the decrease in time of free fall of the bomb are pointed out. The Breguet 460 M twin-engined horizontal bomber is illustrated with specifications. L'Aerophile, March 1936, page 60.

Bombardment in Diving Flight. T. Alexandroff. Technical and tactical considerations in bombing in a dive. The diagrams given illustrate an attack in a dive with a clear sky, with a partially cloudy sky, and with a completely covered sky. Abstract of an article by a Russian officer, published in Corriere della Flotta Aerea No. 12, 1935. Rivista Aeronautica, March 1936, page 363.

Bomber Aircraft. Adoption of a fast twin-engined medium bomber as a standardized type, to the exclusion of the light and heavy classes of bomber, is recommended for an increase in economy of force over the present British system. Question of what constitutes the best type of bomber is discussed with reference to the determination of bomb load, necessity for interchangeability of loads, determination of range, armament and performance of the bomber, past and present British policy, tactical use of the bomber by day and by night, a special night bomber, the bomber abroad, and the supply problem. Royal Air Force Quarterly, April 1936, page 137.

Defense of Battleships from the Enemy. R. Lestonnat. Protection of battleships from artillery, from bombardment of airplanes in horizontal flight and in a dive, from torpedoes launched from a seaplane, and from submarines. Italian translation from L'Illustration, December 1935. Rivista Aeronautica, March 1936, page 347.

Determination of the Position of an Airplane in Space at a Given Instant. Measure of Speeds. Captain Vanzon. Application of previously described methods to the formations of the French air force. Design of the F/26 regulating photographic equipment is explained. Equipment and tests made in controlled flight and in control of sham bombardment are described in detail. Concluded. Revue de l'Armee de l'Air, March 1936, page 313.

Night Bombardment. A. Algasin, F. Kobaleff, A. Beliakoff, B. Katacieff and M. Batascieff. Chapter from "The Tactics of Aerial Bombardment" by five Russians, dealing with night bombing attacks. Conditions of visibility, strength of the bombardment unit, defense against artillery, technical particulars of night bombardment, knowledge of the zone, night equipment of the airport base, indication of the itinerary as the basis of light signals and radio transmission, and the order of operations are discussed. Rivista Aeronautica, March 1936, page 357.

What Chance Has the Pursuit? A French View. C. Rougeron. Relative merits of the heavily armed aerial cruiser, advocated by the Italian General Douhet, and the single-seater pursuit ship are pointed out with emphasis on the advantages of the latter. Speed in formation combat and in individual combat, weight of armament, gun concentration, field of fire, design of turrets, and battle cruisers in formation are discussed and the locations of guns on the Breguet fighter and the Amiot 143 are illustrated. Aviation, April 1936, page 11.

Aviation, the Irresistible Force in the Italian–Ethiopian War. The part aviation played in the Italian–Ethiopian War. Les Ailes, April 23, 1936, page 7.

Bombers Versus Pursuit. Comparison of bomber and pursuit-plane performance, dissociation of bomber formations by means of bombs and rockets, bombardment of bombers by pursuit planes, protection of bombers, and the articulation of bomber formations proposed by Lieutenant MacDonald and Colonel Piacentini are discussed with many charts. The opinions quoted were previously expressed in the American, British and Italian press. Revue de l'Armee de l'Air, April 1936, page 441.

Dazzling Light Process for Passive Defense. R. Ferber. System of using dazzling lights to render it impossible for pilots of enemy aircraft to see a large portion of the ground. Les Ailes, April 16, 1936, page 6.

In the Margin of the London Naval Conference. Attitude of Japan at the Naval Conference theater of the Eastern Pacific and the China seas, Pan American Airways flying ships, and the aero-naval problems of the Pacific are discussed. Illustrations include a group of Japanese single-seater pursuits, and the Kawasaki 93 twin-engined long-distance and medium bombers (with a few specifications in the captions), and the Consolidated XP3–Y Naval flying boat. Revue de l'Armee de l'Air, April 1936, page 452.

Value of Camouflage against Aerial Observation. H. Bouche. Its control by photography and aerial stereoscopy. Revue de l'Armee de l'Air, April 1936, page 371.

Miscellaneous

Bombing Planes to Fight Fire with Chemicals. Bombing planes for this purpose are to be experimented with by the U. S. Forest Service. Brief reference only. Science News Letter, April 25, 1936, page 272.

Light Aircraft Equipment. Some of the more popular items of optional equipment for airplane and pilot now on the British market, including air-speed and turn-and-bank indicators, electrical equipment, wheel brakes, radio, personal equipment, and fire extinguishers briefly reviewed. Flight, April 23, 1936, page 432.